APPENDIX

TYPE AND SUGGESTIVE COURSES OF STUDY

COURSE IN MECHANICAL ENGINEERING IN COLLEGE GRADE INDUSTRIAL SCHOOL

(To supplement page 50)

The course in mechanical engineering aims, first, to give the student a thorough training in such fundamentals as physics, mathematics, and applied mechanics; then, by means of lectures, laboratory work, and drawing-room work, to make him familiar with the various problems with which a mechanical engineer has to deal. He is also given a training in the mechanic arts sufficient to make him familiar with the use of shop tools, foundry practice, forging and pattern work, such knowledge being essential to the successful designer of machinery.

The work in mechanism includes the study of linkages, cams, gear teeth, valve gears of steam engines, and, in the advanced courses, given in the third year, the application of mechanisms to machine tools and to automatic machinery. The course in heat engineering covers thermodynamics, steam engines, boilers, gas engines, gas producers, and power station accessories. Courses are given in Applied Dynamics, Foundations, Factory Construction, Heating and Ventilation, Refrigeration, Industrial Management, and on Physical Metallurgy. The student is given sufficient work in electrical engineering subjects to enable him to handle the ordinary problems which may confront him. A thorough course in Theoretical Hydraulics is followed by Hydraulic Engineering, a course in which both the estimation and the utilization of hydraulic power are discussed. Instruction in drawing extends to the end of the third year, the work finishing with the complete design and calculation of a boiler. The course in machine design, extending through both terms of the senior year, and the course in power plant design, afford the student an opportunity of applying many of the facts learned in preceding years. In the fourth year the student is offered the option of courses in Engine Design, Locomotive Construction, Mill Engineering, and Steam Turbine Engineering.

The laboratory work in steam, hydraulics, and strength of materials is planned follow the classroom work, and thereby assist the student in getting a better grasp of these subjects.

(The whole question of industrial education for college grade has been investigated during the last few years by Professor Charles R. Mann, of the Carnegie Foundation of Learning, New York City.)

COURSE OF STUDY IN MECHANICAL ENGINEERING FOR A COLLEGE GRADE INDUSTRIAL SCHOOL

First Year

First Term	*Second Term*
Mathematics	Mathematics
Plane Trigonometry	Inorganic Chemistry: Laboratory, Lectures and Recitations
Inorganic Chemistry: Laboratory, Lectures and Recitations	Mechanical Drawing and Descriptive Geometry
Mechanical Drawing and Descriptive Geometry	Free-hand Drawing
Free-hand Drawing	Foreign Language
Foreign Language	English
Rhetoric and English Composition	History
Military Science	Military Science
Physical Training	Physical Training

Second Year

First Term	*Second Term*
Mechanism	Mechanism and Valve Gears
Mechanical Engineering, Drawing	Mechanical Engineering, Drawing
Descriptive Geometry	Applied Mechanics
Forging	Foundry
Mathematics	Forging
Physics	Mathematics
Physical Laboratory	Physics
Foreign Language	Physical Laboratory
English	Precision of Measurements
	English

Third Year

First Term	*Second Term*
Heat Engineering	Heat Engineering
Applied Mechanics	Applied Mechanics
Machine Drawing	Mechanism of Machines
Wood-work and Pattern-Making	Mechanical Engineering, Drawing
Mathematics	Boiler Design
Surveying	Engineering Laboratory
History	Electrical Engineering
Political Economy	Physical Metallurgy
General Studies	Vise and Bench Work
	Business Law
	General Studies

Fourth Year

First Term	*Second Term*
Machine Design	Machine Design
Applied Mechanics	Power Plant Design
Testing Materials, Laboratory	General Engineering, Lectures on Aeronautics
Dynamics of Machines	Engineering, Laboratory
Engineering, Laboratory	Hydraulic Engineering
Theoretical Hydraulics	Refrigeration
Electrical Engineering	Heating and Ventilation
Electrical Engineering, Laboratory	Industrial Management
Factory Construction	Machine Tool Work
Foundations	Thesis*
Machine Tool Work	

Options

Engine Design
Locomotive Engineering
Mill Engineering
Steam Turbine Engineering

COÖPERATIVE ENGINEERING EDUCATION

(To supplement page 30)

One of the most successful engineering schools of college grade, the University of Cincinnati, has developed a coöperative plan of education by which the student alternates between practical work and laboratory and classroom work. As the name implies the coöperative scheme of education consists in coöperation between the university and commercial engineering organizations. The students are divided into two sections. While the first section is attending the university for two weeks, the second section is engaged upon outside work. Each student has an alternate, and the bi-weekly exchange is continued until the specific piece of work on which both are engaged is completed.

The freshmen in the case of civil engineers are placed as laborers, with railroads or track-work, with construction companies, working as carpenters, machinists, etc. The minimum wage that the students receive is fifteen cents per hour, and the usual pay is from twenty to thirty cents per hour. This kind of work is continued into their second year, and frequently throughout their second year, in order to give the students a variety of experience. If they make good, they are promoted in the third and fourth years to positions of timekeepers, material clerks, and subforemen. In the fourth and fifth years they are given greater responsibility, and are made foremen, inspectors, and assistant superintendents. Those who desire to stay with the railroads are promoted to the engineering force. The wages of upper-class men gradually increase, depending, of course, on the ability of the students. Fifteen to twenty dollars per week is the present scale. However, a few exceptionally able men are receiving more; for example, a third-year man is rated at $115 a month as assistant superintendent on a large piece of construction work.

COLLEGE GRADE EVENING INDUSTRIAL COURSES

(To supplement page 35)

The following evening courses of college grade are intended to bring the systematic study of science within the reach of young men who are following industrial pursuits and desire to fit themselves for higher positions, but are unable to attend courses during the day. The subjects included in the courses are as follows:

First-Year Mechanical and Electrical Courses. Mathematics, Physics, and Elementary Electricity, Elements of Mechanism, and Drawing.

Second-Year Mechanical Course. Elements of Thermodynamics, the Steam Engine and Boilers, Valve Gears, Applied Mechanics, Elementary Hydraulics, Testing Laboratory, Steam and Hydraulic Laboratory, Mechanism and Machine Design.

Second-Year Electrical Course. Elements of Thermodynamics, the Steam Engine and Boilers, Valve Gears, Steam Laboratory, Direct Current Machinery, Alternating Currents, Electric Distribution, Electrical Testing Laboratory, and Laboratory of Dynamo Electric Machinery.

Building Course. First Year. Mathematics, Physics, Elementary Electricity, Elements of Mechanism and Drawing, Applied Mechanics and Graphic Statics, Steam and Hydraulic Machinery, and Heating and Ventilation. Second Year. Materials and Testing Materials, Structural Design, Foundations, Electrical Machinery, and Electrical Laboratory, Electrical Wiring, Steam Laboratory, and Building Laws, Contracts, Sanitation, etc.

It is the aim to adapt the course to the men for whom the instruction is intended, and to include the study of those principles with which they are not likely to become familiar in practice, and which will give them a fundamental training in those matters that will be of the greatest value to them in the work in which they are engaged.

The instruction embraces recitations, lectures, drawing-room practice, and laboratory exercises; and is given by members of the instructing staff of the day school. Many lectures are fully illustrated by apparatus and experiments. Written tests are given from time to time, and problems are assigned for home work at nearly every exercise. Textbooks are used in many subjects, but in some of the work, where the instruction differs widely from available books, printed notes are supplied to the students at cost. Students are expected to purchase such textbooks, notebooks, instruments, and other material as may be recommended throughout the course.

The scholarship of the students and their ability to continue the courses are determined in part by examinations, but considerable weight is given to the work of the pupil in the term. Those students who fail to keep well up with the work or to profit sufficiently by the instruction are informed that they are not qualified to pursue the course advantageously. Those who complete satisfactorily the required courses of the two years and pass the examinations are given graduate certificates.

The school year begins the last week of September and continues into May. There is a recess of one week at Christmas, and on legal holidays the exercises of the school are suspended. Attendance from 7.30 to 9.30 for three or four evenings a week is required, in addition to outside study.

To be admitted to the first-year class the applicant must be at least eighteen years of age and must pass satisfactorily the entrance examinations. These examinations may be, in a measure, of a competitive nature, as it is likely that the number of applications for admittance will be larger than the capacity of the school. Considerable weight will be attached to the applicant's occupation and practical experience. The courses are open to those only who are ambitious and willing to study and who purpose to complete the full course of two years.

A briefer college course in industrial subjects is offered by the School of Science and Technology of Pratt Institute along different lines, as follows: (To supplement page 30.)

First. Day Industrial Courses in Mechanics, Electricity, and Chemistry, affording a thorough practical and technical training for young men who are ambitious to prepare themselves for leadership in positions of importance and responsibility in this country's expanding industries.

Second. Day Trade Courses in Machine Work, Carpentry and Building, and Tanning, for those who wish practical and theoretical instruction in these trades.

Third. Evening Technical Courses for those employed during the day in mechanical, electrical, and chemical industries and related occupations.

Fourth. Evening Trade Courses for apprentices and journeymen.

Fifth. Courses for the training of mechanic teachers of trades in industrial schools.

The courses offered are as follows:

Day Industrial Courses

Mechanical Industries	A two-year course
Applied Electricity	A two-year course
Applied Chemistry	A two-year course
Applied Leather Chemistry	A one-year course

Day Trade Courses

Machine Construction	A one-year course
Carpentry and Building	A one-year course
Tanning	A one-year course

The time of students in the day courses is fully occupied with required work from 9.10 A.M. to 4.40 P.M. on all week days except Saturday, and students as a rule find it necessary to spend several hours each evening in preparation for the work of the following day.

Evening Technical Courses

Practical Mathematics, first year
Practical Mathematics, second year
Practical Electricity
Industrial Physics
Industrial Electricity
  first year Direct Current Machinery and Electrical Design
  second year Alternating Current Machinery and Electrical Design
Steam and the Steam Engine
Internal Combustion Engine
Strength of Materials
Technical Chemistry
  first year General Chemistry
  second year Machine Design
  third year Quantitative Analysis
Mechanical Drawing and Machine Design
  first year Mechanical Drawing
  second year Machine Design
  third year Mechanism

Evening Trade Courses

Carpentry and Building
Pattern-Making
Plumbing
Foundry Practice
Sheet-Metal Work
Sheet-Metal Pattern-Drafting
Machine Work and Tool-Making
Forging and Heat Treatment

Training Course for Mechanic Teachers

Trade Teaching	Elementary Course
Trade Teaching	Advanced Course

All evening classes are held from 7.30 to 9.30 on Mondays, Wednesdays, and Fridays, from September through March

TRAINING FOR THE DISTRIBUTING PHASE OF INDUSTRY

(To supplement page 19)

The training for the productive phase of industry as described in the previous pages is in production and skill. This means that the emphasis should be on shop training in commercial work rather than theory. The training for the distributive phase of industry should be somewhat different. In the first place, there are certain personal qualifications for a salesman that do not apply to the workman. Second, while the salesman knowledge of his product should be thorough, it should be very different from that of the mechanic.

Large corporations usually send their young men, who have at least an appreciative knowledge of the trades from a school point of view, to the factory for a varying period of time. There is no standard method of training in use among the different firms. Some require[1] the shop training before the men enter the sales offices; others prescribe a short term of office work before the men enter the shops. The latter method seems preferable because the apprentice salesman learns the methods of doing business, and at the end of his office practice knows just what he needs to learn while in the shop.

Any shop training for salesmen should be intensive and not too long. The following represents a method of training salesmen adopted by one firm: The first few days are spent in becoming acquainted with the various officials and the layout of the plant. A study is then made of the machines. One principle common to all machine tools should be made plain to the student, the power applied to the machine is divided into two main branches, the driving of the tool or table, as the case may be, and the feeds. The apprentice should see that it consists of a revolving table and a stationary tool; the rest of the machine consists of a series of levers and covered boxes containing numerous gears, clutches, etc. Show that the power is traced from the belt or motor through the various speed gears and back gears to the pinion which drives the table. It is very desirable for the student to sketch these gear trains on a pad; the very act of putting a construction on paper helps to fix it in one's mind. In the same manner, the feed gearing is traced through from where it leaves the drive gearing to the final tool movement. If any part of the machine is inaccessible, the assembling benches should be visited and the desired part inspected in detail. In this way a fairly good understanding of the function of each lever and clutch is obtained. Then each machine is taken in order.

The next step is to hold an informal consultation with the designer of the tool. With his assistance a number of assembly drawings of the machine in question should be selected from the files; ordinarily about four or five will be sufficient to show the general construction. It is advisable to choose only such drawings as will show the various parts of the machine assembled; too many detailed drawings are likely to cause confusion. These drawings should be gone over carefully with the designer and anything not thoroughly understood should be discussed. Blue-prints should then be made and kept in the salesman's files for reference. It is better to examine the machine before the blue-print, for it is easier to see a thing in reality than on paper.

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[1] Niles Bement Machine Shop.

After the drawings have been studied, it is a good plan for the salesman to make a brief tour through the shop with the designer. By this means every point discussed in the conference is brought home by actual inspection, and the design of the machine is firmly fixed in mind. The concentrated study of that machine may now be considered as ended, though, from time to time, inspections will be made of various types in different stages of erection. Furthermore, it is an excellent plan for the salesman to have frequent chats with the men who operate these machines in different parts of the plant. Much valuable information regarding the output, mode of operation, and special advantages may be obtained from them. This is of service if the salesman's prospect is a "mechanical" man, one who is appealed to from the operator's viewpoint.

The apprentice salesman should cultivate the acquaintance of the workmen, foremen, and designers, as well as other officials. The ability to get along with workmen is a very important quality. Salesmen come in contact with them, and they should know how to correct a false idea instead of displaying any superior knowledge.

After a machine has been studied in the foregoing manner, it is a good plan for the salesman to accompany the inspector on his final tests. Much can be learned from him. He usually has had extensive experience and possesses a veritable storehouse of anecdote and history concerning various machines and their development.

The same plan is followed with each machine, although as the apprentice salesman becomes more experienced he can carry on the study of two or even three machines simultaneously. Along with his practical training the salesman should keep up an extensive technical reading in all lines. A knowledge of present conditions and the trend of improvement and development in his field are of great importance. A further aid is the inspection of any outside plants within convenient distance. On these visits the salesman becomes acquainted with the conditions which his machines have to meet, the methods of manufacture, and the requirements upon the machine-tool builder. He also learns the demands of the users of machine tools. He should transmit this information to his shops, and if he suggests any improvement of value, it should be carried out. Frequently, though, a salesman will offer a machine with certain attachments which are of little service to the user, but are a source of trouble to build. Therefore the salesman should know his machines thoroughly, and also his own factory conditions so that he can guide the purchaser in his demands.

One of the largest concerns in the iron and steel trade believes that high-salaried executive officers may be as much benefited by a course of industrial training as the ordinary employee who is tending a machine, or a salesman, and has established a school for training executives. The students in this school are from forty to sixty years of age, and the average age is fifty-two. The course of instruction includes shop practice, administration, and theory. The course of instruction extends over six weeks, during which time the students give their entire time to the school work. Their salaries continue as usual during this time, and their traveling expenses in visiting different works of the company during the course are paid. The cost of the school apart from these items is about $35,000 per annum. The usual routine is to spend a forenoon in the shop and the afternoon in attending lectures, while the evening is devoted to the study of textbooks. The students are given examinations at stated intervals, and their markings in the examinations are sent to the head office of the company.

INDUSTRIAL COURSES OF SECONDARY GRADE IN A GENERAL COURSE OF STUDY

(To supplement page 58)

The aim of the Industrial Course is to prepare students as fully as possible for definite industrial occupations.

In the course of instruction for boys practical shop-work and mechanical drawing are emphasized and much time is devoted to them. Adequate attention is also given to necessary academic subjects, including English, mathematics, and science. In the first two years the shop-work is general and fundamental, and includes wood-working, pattern-making, foundry practice, forging, machine work, the use and care of tools and machines, qualities of materials and their production, and a study of the fundamental principles of construction. All the work is educative as well as practical. At the end of the second year, if the pupil exhibits special ability in any direction, he may be permitted to specialize along this line, in order that he may be the better fitted for the industrial career which he desires. In these courses the required academic work is closely related to the industrial work. The courses in the day school will include six hours, divided into seven periods.

INDUSTRIAL COURSE FOR BOYS[1]

	Periods	Points
Grade 9A (1st Year)		
Required:		
Applied Mathematics	4	4
English	5	5
Elementary Science	4	4
Wood-work	6	4
Forging	4	2
Mechanical Drawing	6	3
Grade 9B (1st Year)		
Required:		
Applied Mathematics	4	4
English	5	5
Elementary Science	4	4
Wood-work	6	3
Machine Shop Practice	6	3
Mechanical Drawing	6	3
Grade 10A (2d Year)		
Required:		
Applied Mathematics	4	4
English	4	4
Industrial History	4	4
Pattern-Making	6	3
Foundry Practice	6	3
Mechanical Drawing	6	3

	Periods	Points
Grade 10B (2d Year)		
Required:		
Applied Mathematics	4	4
English	4	4
Industrial History	4	4
Pattern-Making	6	3
Foundry Practice	6	3
Mechanical Drawing	6	3
Grade 11A (3d Year)		
Required:		
English	4	4
Physics	6	5
Mechanical Drawing	6	3
Carpentry or	12	6
Cabinet-Making, or	12	6
Pattern-Making, or	12	6
Foundry Practice, or	12	6
Machine-Shop Practice, or	12	6
Printing	12	6
Grade 11B (3d Year)		
Required:		
English	4	4
Industrial History	4	4

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[1] From Course of Study, Dickinson High School, Jersey City, N.J.

	Periods	Points
Physics	5	5
Mechanical Drawing	6	3
Carpentry, or	12	6
Cabinet-Making, or	12	6
Pattern-Making, or	12	6
Foundry Practice, or	12	6
Machine-Shop Practice, or	12	6
Printing, or	12	6
Electrical Construction	12	6

Grade 12A (4th Year)

Required:	Periods	Points
Civics	4	4
Shop Mathematics	4	4
Geometry*	4	4
Mechanical Drawing	6	3
Carpentry, or	20	10
Cabinet-Making, or	20	10
Pattern-Making, or	20	10
Foundry Practice, or	20	10
Machine-Shop Practice, or	20	10
Printing, or	20	10
Electrical Construction, or	16	8
Machine Drafting, or	16	8
Architectural Drafting	16	8

Grade 12B (4th Year)

Required:	Periods	Points
Civics	4	4
Shop Mathematics	4	4
Geometry and Trigonometry*	4	4
Mechanical Drawing	6	3
Carpentry, or	20	10
Cabinet-Making, or	20	10
Pattern-Making, or	20	10
Foundry Practice, or	20	10
Machine-Shop Practice, or	20	10
Printing, or	20	10
Electrical Construction, or	16	8
Machine Drafting, or	16	8
Architectural Drafting	16	8

* Required only with Electrical and Drafting Courses.

SPECIAL INDUSTRIAL COURSES (Two years)[1]

Each pupil will be required to select Carpentry or Cabinet-Making, or Pattern-Making and Foundry Practice, or Machine-Shop Practice, or Printing, as his specialty.

Grade 9A (1st Year)

Required:	Periods
Carpentry, or	18
Cabinet-Making, or	18
Pattern-Making and Foundry Practice, or	18
Machine-Shop Practice, or	18
Printing	18
Mechanical Drawing	6
Shop Problems	4
English	4

Grade 9B (1st Year)

Required:	Periods
Carpentry, or	18
Cabinet-Making, or	18
Pattern-Making and Foundry Practice, or	18
Machine-Shop Practice, or	18
Printing	18
Mechanical Drawing	6
Shop Problems	4
English	4

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[1] From Course of Study, Dickinson High School, Jersey City, N.J.

Grade 10A (2d Year)	Periods	Grade 10B (2d Year)	Periods
Required:		Required	
Carpentry, or	18	Carpentry, or	18
Cabinet-Making, or	18	Cabinet-Making, or	18
Pattern-Making and Foundry Practice, or	18	Pattern-Making and Foundry Practice, or	18
Machine-Shop Practice, or	18	Machine-Shop Practice, or	18
Printing	18	Printing	18
Mechanical Drawing	6	Mechanical Drawing	6
Shop Problems	4	Shop Problems	4
English, including Selected Readings, relating to Industries and Civics	4	English, including Selected Readings, relating to Industries and Civics	4

COÖPERATIVE HIGH-SCHOOL COURSE

(To supplement page 86)

An excellent part-time system of education of high-school grade is seen in the Fitchburg Coöperative High-School Course. Fitchburg is a manufacturing city of about 40,000 inhabitants, with various types of industries. These manufacturers have felt the need for a long time of technically trained boys of high-school training. One of the successful manufacturers in the city heard Professor Schneider describe his part-time engineering school one evening and he was impressed with the simplicity and practicability of the plan, and judged that such a scheme could be adapted to high-school students who wished to learn a trade and continue their education at the same time.

A committee was appointed from the different manufacturers to consider the advisability of such a plan in the local high school. The committee reported a plan for a combination shop and school course, offering the use of their shops for the practical instruction of apprentices if the school would provide the necessary academic instruction. The school committee agreed to this plan and many manufacturers entered into the agreement.

The course outlined is of four years' duration, the same as the regular high-school course. The first year is spent wholly in the school and the next three years in the shop and school — one week in the shop and one week in the school. In order to carry out this scheme the manufacturers take boys in pairs so that by alternating they have one of the pair always at work, and likewise the school is provided with one of the pair.

The Fitchburg scheme of industrial education was put into operation August 1, 1908, with twenty-two people, eleven in the shop and eleven in the school. The parents agree that the boy will stay at this work for three years, and the manufacturer on his part agrees to teach him the various branches of the trade designated in the agreement. In order to make this binding the parents must file a bond of fifty dollars.

Each Saturday morning the boy who has been at school that week goes to the shop in order to get hold of the job his mate is working on, and be ready to take it up Monday morning when the shop-boy goes to school for a week. When there is a vacation week in school, work is provided in the shop, so that the boy does not loaf around the streets. The shop-work consists in instruction in the operation of lathes, planes, drilling machines, bench and floor work, and other machine work. The school-work is twenty weeks a year. Since it is such a short course only such subjects are taught as are of practical value to the student in the pursuit of a livelihood. The regular courses of high-school study were discarded, precedent ignored, and a new course of study made out.

One great objection to coöperative part-time work in high school is the fact that the vast majority of pupils enter the distributing, rather than the productive, branch of trade life.

One of the best examples of the successful operation of a part-time system of education of intermediate school type is the Beverly Industrial School.

Beverly is a small manufacturing city with one very large industry, the manufacture of shoe machinery by the United Shoe Machinery Company. The school authorities and this large corporation have entered into an agreement to furnish industrial education to young men between the ages of fourteen and twenty-five. Briefly, the plan of coöperation is the following:

A separate department is organized in the factory of the United Shoe Machinery Company and equipped with all necessary machine tools for the accommodation of twenty-five boys at one time. Two groups of twenty-five alternate between the factory and the schoolhouse. The company furnishes all materials and keeps the accounts and purchases the product at established prices. The company makes up the deficit between the earnings of the practice shop as shown by the accounts and the cost of maintenance of the practice shop including the salary of the instructors while in the shop. The hiring of the shop instructor or foreman and the management of the shop are in the hands of the School Committee on Industrial Education. This committee provides in the school instruction in shop mathematics, including the use of micrometers and other instruments of precision, mechanics, chemistry of the different kinds of materials used in the factory, free-hand sketches with dimension blue-print reading, mechanical drawing, English, civics, industrial economics, business forms and practice. The excellent laboratories and other equipment of the high school are available for the use of the industrial school afternoons and evenings and a portion of another school is used in the forenoons, as required. In this way excellent buildings and equipment are used at no additional cost to the city of Beverly and the cost of maintenance is reduced to a minimum. No pupil, however, is bound by any agreement or indenture to continue to the end of any course. The only entrance requirements for a boy are that he shall have attained the age of fourteen years and shall have completed satisfactorily the sixth grade, at least, in the public elementary schools or an equivalent. The requirements of a pupil remaining in the school are satisfactory conduct and a reasonable degree of proficiency in his work. The greater stress is laid on the shop-work in case of doubt.

DAY INDUSTRIAL SCHOOL

(To supplement page 59)

The following trades are usually taught in a day industrial school:

Carpentry
Architectural draftsman
Cabinet-maker
Machinist
Mechanical draftsman
Electrician
Engineer
Automobile repairing

Carpentry. The course providing training for the trade of carpenter consists of shop practice and science, study of building materials, architectural drawing, mathematics, English, and civics.

Architectural draftsman. This course differs from the carpenter's course in having much of the shop-work replaced by work in the drafting-room, on building construction.

Cabinet-making. This course differs from the carpenter's course in having more time devoted to office furniture, etc., than to the building trade work.

Machinist. This course, in addition to English and civics, includes machine-shop work, the mathematics underlying machine-shop work, study of materials, drawing, and some work in steam and electricity. The shop-work consists of practice in the usual operations common to machine-shop work.

Mechanical draftsman. The mechanical draftsman's course is similar to the machinist's course with much less shop-work, and more practice in the drawing-room on machine-shop work.

Electrician. This course deals with practical and theoretical electricity, and includes electric wiring, building motors, winding armatures, testing and repairing circuits, and practical experience in the electric power station, etc. In addition there is special mathematics applied to electrical work, and English and civics is also taught.

Engineer. This course deals with the theory and practice of steam work. It includes in addition English and civics, some machine-shop practice, and mathematics.

Automobile repairing. The automobile repairing course usually consists of work similar to that of the machinist's course, with special shop-work on the automobile and the study of its operation.

MILLWRIGHTING

In every manufacturing community there is a demand in the factories for a type of millwright, or "handy man," who is able to do rough carpentry and pattern-making, general repair machine work, take care of belts and gears, motors and dynamos, do painting and glazing, and electrical wiring of a rough character. This work does not demand the skill of a tool-maker or cabinet-maker, and will appeal to the boy of ordinary mechanical ability.

COURSE OF STUDY (*Two years*)

	Time Allotment
English, history, civics, etc.; shop mathematics, sketching and blue-print working	20 per cent
Laboratory practice and observation of the following subjects: Concrete and masonry, applied chemistry and physics, hydraulics and plumbing; general knowledge, rather than specific ability is required in these subjects	30 per cent

Shop practice in the following subjects: Rough carpentry and pattern-making, general repair machine work, care of belts and gears, care of motors and dynamos, and electrical wiring of a rough character, painting, glazing, and plumbing......50 per cent

Method of teaching. The method of teaching must be based upon the existence of a maintenance problem in a factory. Some work of this kind can, no doubt, be found in every school, and in order to make the work efficient it is probable that some outside sources of supply can be found. Arrangements should be made to let the boys work on a part-time basis in a factory, or have them, one at a time, spend some time in a factory or mill. In order to secure the highest degree of correlation it is desirable that the first-year shop-work should be based upon the project method; that during the second year, so far as practicable, the technical work be separated from the shop-work and handled upon a laboratory basis. Correlation should be carried out as far as possible.

Machine-shop work. Repair machine work differs from the regular production work chiefly in the lack of special machines in equipment, and in the fact that the machinists usually go with their jobs from machine to machine. In many cases the equipment is either inadequate or antiquated, and the machinists have to exercise considerable ingenuity in doing their work with the means at their disposal. These conditions should be duplicated as nearly as possible in the shop-work of this course. The course should include such work as ordinary operations on the sensitive and heavy duty drill press, milling, plain and simple index milling, including the cutting of plain gears, plain shaper work and considerable lathe work, including work on the cutting lathe.

Blacksmithing. This work could be adequately carried through with one or two small portable forges placed in the machine shop. Work of this kind should include brazing and some hardening and tempering.

Electrical work. The electrical work should include a study of the gross anatomy of the dynamo and motor. The pupils should learn the names and functions of parts, assemble and disassemble motors, and should become familiar with method of control, reversing, starting, etc., low tension work with number 18 wire; the usual series of board problems can be worked out with bells, annunciators, etc. Practice should be given in wiring, exposed wiring of the mill type, including drilling in concrete and masonry, and some work with conduits, connecting up dynamos and motors according to the instructions furnished with these machines. House-wiring, as distinguished from mill-wiring, should not be attempted to any extent. Maintenance work on interior circuits, including maintenance and simple repairs on dynamos and motors, should also be included. Considerable practical work can be found in the school itself. This can be supplemented by outside work through coöperation of the mills or from the school department.

Carpentry work. Carpentry work should be of the character required of the mill machinist. The boy should carry the job through, both at the bench and, so far as safety permits, at the machines. Work should be entirely in the cheaper woods and should not call for a high degree of accuracy or finish. The following subjects should be covered in the course: butt, lap, and half-lap joint (no dovetailing); putting up rough partitions and floors; building stagings and scaffoldings, boxes and trucks. The aim is to turn out a comparatively rough, handy carpenter, and not a cabinet-maker; hence furniture-making should not be included.

Steam piping. The object of this work should be to turn out a mechanic who can cut the ordinary iron piping and who knows how to cut threads so as to make a tight joint, working from a sketch plan. It should include the use of the hack saw, the cold chisel, hand dies for threading, and the operations of making up a threaded and union joint with different types of valves, elbows, tees, etc. This work cannot very well be done on an exercise basis and therefore should be included in the shop-work, because the only way to test the job is by putting steam into it.

Pattern-making. The mill machinist is often called upon to make simple patterns, mainly where a piece of repair work is needed. For example, a gear breaks and a simple pattern is made from the broken gear, sent to a local foundry, and the casting is made in the machine shop. Usually the important factor here is time, rather than extreme care in the waste of iron. Solid patterns and simple core patterns cover all the demands of this course. These patterns should be made in the cheap wood, without extreme regard to accuracy. Instruction should include the use of the shrink rule for iron and brass, and provision should be made for the boy who has made the pattern to visit the factory so that he will understand the process of making the mold.

Painting and glazing. The aim of this work is merely to turn out a worker who can set an ordinary pane of glass. Instruction would therefore include removing broken glass, cleaning out the putty and old tacks, putting in the new glass, tacking and puttying the work.

Concrete and masonry. *Concrete.* Mixing, control of properties of concrete by changing the ingredients, good and bad mixtures for different purposes, pouring, setting, forming, dressing, etc., making paths, concrete forms of different kinds, as opportunity offers. *Masonry:* Brick, hollow, tile, etc., laying, binding, arching, taking down old brick-work, the laying to line of masonry, mortar, the ingredients of mortar, control, conditions affecting settling, etc. This work should be largely laboratory in character, following the lines of the New York Trade School, where work of this kind is first set up and then torn down. This should be supplemented by some construction work.

Engines and boilers. The aim of this course is to acquaint the pupil, in a general way, with the construction, operation, and function of steam units. This should include a general knowledge of names and functions of parts, and of the slide-valve engine, the cross-compound engine, functions of accessories, such as feed pumps, injectors, gauge-glasses, steam gauges, ash-pits, different types of boilers, etc. Laboratory study along these lines can be carried on with a large number of materials secured from the junk heap and fitted for this purpose through the melting out of certain parts, so as to include the insides. In addition, a study of the gas engine should be included.

Drawing. The aim of this course is to give some degree of familiarity with reading all sorts of plans — piping plans, electrical wiring plans, machine-shop blue-prints, carpentry plans, plumbing plans, etc.; (1) exercises in reading simple plans of all the above; (2) exercises in sketching layouts, especially where the pupil is required to trace out a circuit, electrical, steam, or plumbing, etc.; (3) elements of mechanical drawing, simple work in the use of instruments and projections.

Trade mathematics. This course should include elementary instruction in rough trade methods of computing material, such as lumber, brick, concrete, time, cost, etc., as given in *Vocational Mathematics.*[1]

Applied science. Applied science may be taught on a laboratory basis, with practical demonstrations. It should include a rather general knowledge of a number of the simpler facts of physics and chemistry as applied to trades, such as the effect of temperature upon material, expansion, contraction, melting, boiling, distillation; a little study of light, based upon the taking of photographs, properties of metals, etc., and a notion of the terms used in hydraulics, such as "head of water," "water flow," etc., which should be based upon a study of the local water supply system. Pupils should be taught to explain practical questions, such as why concrete sets; how a furnace is built to give good combustion; what makes steam pressure; how it is controlled; what makes a dry boiler burst; how a fusible plug works, why a saw-tooth roof is used on a weave shed to get good light; how electric lights are laid out in order to give proper illumination, etc.[1]

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[1] See *Vocational Mathematics*, by W. H. Dooley.

SECONDARY DAY INDUSTRIAL SCHOOLS

The following are the departments and courses of study in the day work of the Holyoke Vocational School:

Department of Carpentry and Building

First Year

Shop Practice
Trade Mathematics
Trade English
Trade Drawing

(About 80 per cent on shop floor)

Applied English
Applied Mathematics
Hygiene
Physical Training

(About 60 per cent classroom)

Second Year

Shop Practice
Trade Mathematics
Trade Science
Trade Hygiene
Trade English
Trade Drawing
Shop Management

(From 50 to 60 per cent shop-work)

English
Civics
Hygiene
Mathematics
Industrial History
Physical Training

(From 40 to 60 per cent classroom)

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[1] See *Applied Science for Metal-Workers and Wood-Workers*, by W. H. Dooley.

Third Year

Shop Practice
Shop Mathematics
Shop Drawing
Shop Management
(From 50 to 60 per cent shop-work)

English Literature
Citizenship
Hygiene
Mathematics
Industrial History
Physical Training
(From 40 to 50 per cent classroom)

DIRECTOR OF INDUSTRIES Bengal.

Fourth Year (first half)

Shop Practice
Shop Mathematics
(50 per cent shop-work)

English
Mathematics
Mechanics
Drawing
Hygiene
Physical Training
(50 per cent classroom)

Fourth Year (second half)

The apprentice enters the trade. A record of his work is kept. This record becomes a part of the complete trade record of the boy.

DEPARTMENT OF MACHINE-SHOP PRACTICE

First Year

Shop Practice
Trade English
Shop Management
Trade Mathematics
Trade Drawing
Trade Hygiene
(80 per cent shop-work)

Applied Mathematics
Applied English
Hygiene
Physical Training
(20 per cent classroom)

Second Year

Shop Practice
Trade Mathematics
Trade Science
Trade English
Trade Hygiene
Shop Management
(50 to 60 per cent shop-work)

Applied English
Applied Mathematics
Hygiene
Industrial History
Citizenship
Physical Training
General Mechanical Drawing
(40 to 50 per cent classroom)

Third Year

Shop Practice
Trade Mathematics
Shop Management
Trade English
Trade Science
Trade Hygiene
(50 to 60 per cent shop-work)

English Literature
Citizenship
Hygiene
Mathematics
Industrial History
Physical Training
General Mechanical Drawing
(40 to 50 per cent classroom)

Fourth Year (first half)

Shop Practice
Related Trade Subjects
(60 per cent shop-work)

English
Science
Hygiene
Mathematics
Drawing
Physical Training
(50 per cent classroom)

Fourth Year (second half)

The apprentice enters the trade and the record is kept of his work.

DEPARTMENT OF PATTERN-MAKING

First Year

Shop Practice
  Moulding
  Core-Making
Trade Mathematics
Trade English
Trade Drawing
Shop Management
(80 per cent shop-work)

Applied English
Applied Mathematics
Hygiene
Physical Training
(40 per cent classroom)

Second Year

Shop Practice
Trade Mathematics
Shop Management
Trade English
Trade Hygiene
Materials
(50 to 60 per cent shop-work)

Applied English
Applied Mathematics
Hygiene
Industrial History
Citizenship
Physical Training
General Mechanical Drawing
(40 to 50 per cent classroom)

Third Year

Shop Practice
Trade Mathematics
Shop Management
Trade English
Trade Science
Trade Hygiene
(50 to 60 per cent shop-work)

English
Citizenship
Hygiene
Mathematics
Industrial History
Physical Training
General Mechanical Drawing
(40 to 50 per cent classroom)

Fourth Year (first half)

Shop Practice
Related Trade Subjects
(50 per cent shop-work)

English
Science
Hygiene
Mathematics
Drawing
Physical Training
(50 per cent classroom)

Fourth Year (second half)

The apprentice enters the trade. A record is kept of his work which becomes a part of the completed trade record of the boy.

PRINTING

First Year

Shop-Work
  (1) Composition
  (2) Press-Work
Trade Mathematics
Trade English
Trade Drawing
Trade Hygiene
(80 per cent shop-work)

Applied English
Applied Mathematics
Civics
Hygiene and Physical Training
(20 per cent classroom)

Second Year

Shop Practice
Trade Mathematics
Materials of Trade
Trade English
Trade Hygiene
Trade Design
(50 to 60 per cent shop-work)

Applied English
Citizenship
Hygiene
Applied Mathematics
Industrial History
Physical Training
(40 to 50 per cent classroom)

Third Year

Shop Practice
Trade Mathematics
Materials of Trade
Trade English
Trade Science
Trade Hygiene
(50 to 60 per cent shop-work)

English (Literature)
Citizenship
Hygiene
Mathematics
Industrial History
Physical Training
English Composition
(40 to 50 per cent classroom)

Fourth Year (first half)

Shop Practice
Related Trade Subjects
(50 per cent shop-work)

English
Printing Design
Mathematics
Hygiene
Physical Training
(50 per cent classroom)

Fourth Year (second half)

The apprentice enters the trade. A record of his work is kept. This record becomes a part of the complete trade record of the boy.

SHORT UNIT COURSES

(To supplement page 56)

Unit courses should be very specific. To illustrate: A course in any branch of cotton manufacture should not be simply cotton manufacture, but divided into units as follows:

Carding and Spinning Department[1]

Picking and Carding — one year, two evenings a week.
Combing — one year, two evenings a week.
Drawing and Roving Frames — one year, two evenings a week.
Ring Spinning and Twisting — one year, two evenings a week.
Mule Spinning — one year, two evenings a week.
Cotton sampling — one term, two evenings a week.
Advanced Calculations in Carding and Spinning — one year, one evening a week.

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[1] From Course of Study, Bradford Durfee Textile School, Fall River, Mass.

Weaving and Warp Preparation Departments

Spooling, Warping and Slashing — one term, two evenings a week.
Plain Weaving and Fixing — one year, two evenings a week.
Fancy Weaving and Fixing — one year, two evenings a week.
Weaving and Fixing (French Class) — one year, two evenings a week.
Weaving and Fixing (Portuguese Class)—one year, two evenings a week.
Advanced Calculations in Weaving — one year, one evening a week.

Designing Department

Elementary Designing and Cloth Construction — one year, three evenings a week.

Advanced Designing and Cloth Construction — one year, three evenings a week.

Jacquard Designing — one year, two evenings a week.

Knitting Department

Special Knitting — one year, two evenings a week.

Smaller units may be formed as follows:

UNIT COURSE ON MOTORS AND GENERATORS IN THE ELECTRICAL TRADE WITH DATES

Jan. 6th. Lesson I
Organization of class General explanation of topics in the course.

Jan 10th. Lesson II.
Magnetism. Permanent and electro-magnets

Jan 12th. Lesson III.
Principles of solenoid.
Rules of thumb.

Jan. 17th Lesson IV
Electrical units.
1. Volt, ampere, watt, ohm
2. Ohm's law.

Jan. 19th. Lesson V.
Direct current motors.

Jan. 24th. Lesson VI.
Alternating current motors.
1. Single phase.
2. Polyphase.

Jan 26th Lesson VII.
Alternating current motors (*continued*).

Jan 31st Lesson VIII.
Motor troubles
1. Direct current.
(a) Location.
(b) Remedies.

Feb 2d Lesson IX.
Motor troubles.
2. Alternating current
(a) Location
(b) Remedies.

Feb 7th. Lesson X
Motor application.

Feb. 9th. Lesson XI.
Motor application (*continued*).

Feb. 14th Lesson XII.
Motor wiring.

Group of Unit Courses for Carpenters

Course I. House framing

- a. Braced or balloon frame construction
- b. Framing joists around chimney stair and other openings

Course II. Roof construction

- a. Figuring length of
    - 1. Hips
    - 2. Valleys
    - 3. Common
    - 4. Jacks
- b. Steel square or graphic method
- c. Roofs over bays

Course III. Stair-building

- a. How to lay out story rod
- b. Pitch board
- c. Proportioning treads and risers
- d. Rough stair stringer
- e. Platform stairs
- f. Winding stairs
- g. Open and closed stairs
- h. Newelled stairs
- i. Hand-railing
- j. Spandrel

Course IV. Inside finish

- a. Door and window construction
- b. Wainscotting
- c. Hanging doors
- d. Construction of mantels
- e. Construction of china closets

Group of Unit Courses in Drawing for Carpenters

Course I. Blue-print reading

- a. Detail sketching
- b. Billing of material

Course II. Making full-size detail layout for mill work

Note. — This work will be confined to inside finish.
The following points will be covered:

- a. Beamed ceilings
- b. Mantels
- c. China closets
- d. Stair work

Course III. Drawing and tracing for carpenters

Note. — This course is intended to teach carpenters how to make drawings for their own use in the trade. It will cover the following points:

- a. Small structures
    - 1. Garages
    - 2. Storehouses, etc.
- b. Alterations
    - 1. Additions
    - 2. Store and office work

Short Unit Courses in Fine Cabinet-Making

1. Drafting. How to make working drawings. Use of scale drawings. Geometry applied to wood-work.
2. Laying out rods. Their object. Preparation of cutting lists.
3. Mouldings and their application.
4. Mitering and halving of angles. Mitering of curved and straight moulding. Principles to be observed around unusual angles.
5. Veneering. Preparation of grounds. Veneering with cauls; hammer method. Treatment of veneers. Veneering shaped surfaces. To apply tortoise shell treatment of celluloid and metal inlay. Making of fancy banding lines in circular work.
6. General construction of fine cabinet work, including: sideboards, dining-tables, gate-leg tables, center tables, sectional bookcases, bureaus, rolltop desks, writing-tables, china cabinets, corner cabinets, card-tables, bedsteads.
7. Showcases. Air-tight construction.
8. Orders of architecture. Dimensions of the classic orders of architecture applied to cabinet-work.
9. Paneling. Construction and fixing of paneling.
10. Styles. Characteristics of English and French styles. Suitable details for each period.

Unit Courses in Machine-Shop Practice

Course I. Making fits

a. Straight-bore fit
b. Straight-turn fit
c. Tight and running fit
d. Shrink and force fit

Course II. Screw-cutting

a. V-thread
b. Square thread
c. Acme thread
d. Grinding tools
e. Setting tools
f. Change gears and manipulation of machine

Course III. Lathe-work

a. Lathe-work on tool-making
b. Making of taps, reamers, and cutters
c. Use of the taper, backing off and relieving attachment

Course IV. Milling Machine

a. Spiral work on cutters
b. Bevel gearing

Course V. General milling machine work

a. Taps
b. Reamers
c. Cutters
d. Use of dividing head

Course VI. Universal grinding

a. Handling of machine
b. Internal grinding
c. External grinding
d. Surface grinding

Course VII. Shop arithmetic for machinists

a. Pulley speed and sizes
b. Gear speeds
c. Simple gear trains
d. Compound gearing
e. Cutting speeds of lathe
f. Cutting speeds of planer
g. Change gears for screw thread cutting
h. Taper turning
i. Indexing

Course VIII. Blue-print reading for machinists

a. Shop sketching
b. Analysis of assembly drawing
c. Conventional shop methods

TRADE EXTENSION COURSE IN ELECTRICITY

Divided into units —

Each unit is conducted twice a week for eight weeks.

1. Electricity and magnetism.
2. Batteries.
3. Blue-print reading and drawing for electricians.
4. Electrical circuits.
5. Direct current generators.
6. Direct current motors.
7. Inside wiring for light and power.
8. Meters and meter testing.
9. Power plant operation.
10. Alternating current generators.
11. Transformers.
12. Alternating current motors.

Four courses can be carried on at one time.

TRADE EXTENSION COURSES

Unit Courses in Textile Design

(Holyoke Vocational School)

Course I. Stock

a. Cotton
b. Silk
c. Wool

Course II. Weave formation

- a. Use of design paper
- b. Construction of weaves
- c. Foundation weaves

Course III. Twill weaves

- a. Regular twill weaves
- b. Effect of color on plain and twill weaves

Course IV. Calculations for yarn

- a. Cotton
- b. Spun silk
- c. Wool and worsted

Course V. Fancy twill weaves — Reduction and drafting of weaves

- a. Reducing weaves
- b. Drawing in drafts
- c. Harness chain drafts

Course VI. Fabric analysis

- a. Cloth calculations

Warp preparation and weaving will be taken up with work in textile design as a means of demonstrating and developing instruction in weave formation.

Loom-fixing

1. Setting-up of looms
2. Leveling of looms
3. Timing of loom parts
4. Setting-up of plain and fancy weaves
5. Remedying defects in weaving
6. Instructions on automatic looms
7. Loom-fixing in general

Unit Courses in Printing

(Holyoke Vocational School)

Composition

Course I. Book composition

1. Justification
2. Division of words
3. Proof-reader's marks
4. Paragraphs and indention
5. Tabular work
    - a. Two or more columns justified in one measure
    - b. With rules and box heads

Course II. Special composition

- A. Newspaper advertising
- B. Book and job advertising

    Business cards, tickets, programs, booklets, title-pages, letter-heads, billheads, statements, etc.

Course III. Imposition

- a. For job press
- b. For cylinder press
  - Margins, register
  - Hand and machine folds

Paper and cardboard in printing
- Finish
- Weight
- Adaptability
- Trade Customs

Course IV. Estimating

- a. The individual job
  - Casting up copy
  - Cost of composition
  - Cost of press-work
  - Cost of binding
  - Cost of shipping
  - Cost of stock
  - Profit
  - Costs in detail
- b. Composition and press-work
  - Labor
    - Productive and non-productive time
  - Supervision
  - Interest in investment
  - Depreciation
  - Insurance
  - General overhead:
    - Telephone, supplies, rent, etc.

Press-work

Course I. Press-feeding

1. Handling paper
2. Laying printed sheets
3. Keeping color on job

Course II. Elementary press-work

1. Patching up
2. Marking out
3. Putting on overlay
4. Putting on underlay

Course III. Advanced press-work

1. Making plates type-high
2. Cutting overlays
3. How to place a cut overlay

Course IV Printing-inks

1. Mixing colors
2. What inks are best suited to different stocks
3. When and how to use varnishes, dryers, and reducers

Course V Embossing

1. How to make ready
2. Wax method
3. Kalsomine method
4. Glass method

STEAM ENGINEERING COURSES

(Holyoke Vocational School)

Course I Boilers and Accessories

1. Tubes
   - Heads
   - Dry sheet
   - Settings

2. Closing in line
   Grates
   Bridge walls
   Combination chamber
   Back connections
   Fire bricks and their use

3. Furnace mouths
   Blow-off pipes
   Nozzles
   Hand-holes
   Man-holes
   Braces

4. Check-valves
   Feed-pipes
   Fusible plugs
   Safety-valves
   Water column

5. Bagging and blisters
   Injectors
   Inspirators
   Damper
   Regulators

6. Connecting boilers in batteries
   Thickness of fires
   Steam gauges

7. Steam traps and their uses
   How to take care of them

8. Reducing valves
   Foaming in boilers
   Sediment and its effect

9. Pumps — care and operation of same
   Boiler compound
   Scale and its effects

10. Upright boilers
   Water tubes
   Construction of different types

Course II.

1. Heating system
   a. Direct
   b. Indirect
   c. Combined system
2. Feed water heaters
   a. Open heaters
   b. Closed heaters
   c. Economizers
3. Stack, the proper size for different capacity
4. Circulation of steam
   a. Return traps
   b. Air-valves
5. Pitting in boilers, its cause and how to remedy
   To lay up for summer
6. Inspection of boiler and systems
   Priming in boilers — How to prevent
7. Return pumps
   Receivers
8. Draft
   a. Natural
   b. Forced
   c. Induction
9. Hot-water system
   Double and single pipe system

Course III.

1. Steam engines
   a. Slide valve
   b. Construction of
   c. Eccentric
   d. Setting valve
2. Green engine
   a. Construction of
   b. Setting valves
3. Putnam engine
   a. Construction of
   b. Setting valves

4. Fitchburg engine
    a. Construction of
    b. Valve setting
5. Corliss engine
    a. Construction of
    b. Setting valves
6. Engine pistons
    a. Construction of different types
7. Different types of connecting rod ends
8. Engine governors
    a. Throttle governors
    b. Centrifugal governors
    c. Inertia
    d. Dead wheel
9. Turbines
    a. Vertical
    b. Horizontal
    c. Mixed pressure
    d. Extraction
    e. Impulse and reaction types
10. Indicators
    a. Construction of
    b. How to use

Course IV

1. Mathematics as applies to steam engineering
   Reading and computing horse-power of indicator diagram
2. Computing evaporation of water from indicator diagram
3. Ratio and expansion of steam in cylinder
4. Figuring size of safety-valves for different pressures and grate areas
5. Efficiency of different kinds of boiler joints
6. Factors of evaporation
7. Speed of engine governors
8. Bursting and safe working pressure of boilers
9. Range of cut-off of different types of engines
10. The use of slide rule in steam engine practice
11. Condensers

UNIT COURSES FOR STEAM ENGINEERS AND FIREMEN

(Holyoke Vocational School)

Course I. Boilers

a. Construction of different types
b. Figuring efficiency of joints
c. Bracing and staying
d. Ascertaining bursting and safe working pressure

Course II. Boiler accessories

a. Feed pumps
b. Feed piping
c. Feed water heaters
d. Boiler compounds
e. Scale and its effects

Course III
- A. Air compressors
  - a. Construction and working of
- B. Plain slide-valve engine
  - a. Construction and working of
  - b. Valve setting
  - c. Governing
  - d. Indicating

Course IV. Corliss and automatic engines
- a. Construction and working of different types
- b. Valve setting — governing
- c. Indicating and computing
- d. Horse-power

Course V
- A. Steam piping
  - a. How located
  - b. Figuring size for certain work
  - c. Covering of
  - d. Loss from radiation
- B. Steam traps
  - a. Where located
  - b. Construction of

EVENING RECREATIONAL WORK FOR BOYS

(To supplement page 69)

Recreation and physical education
- a. Personal hygiene
  - 1. Shower baths
- b. Athletic games
  - 1. Ringtoss
  - 2. Tag
  - 3. Pass-ball
  - 4. Volley-ball
  - 5. Hand-ball
  - 6. Basket-ball
  - 7. Dramatic games
- c. Table games
  - 1. Checkers
  - 2. Chess, etc.

MANUAL TRAINING

(New York State Department of Education)

(To supplement page 181)

Seventh Year

Suggestive outline for bench work in wood

Projects

1. Necktie rack
2. T square
3. Drawing board
4. Towel roller
5. Broom holder
6. Hatrack

7. Bookrack
8. Shoe box
9. Loom
10. Stationery holder
11. Wastebasket
12. Flower box
13. Bookshelves
14. Magazine rack
15. Negative rack
16. Printing frame
17. Jardinière stand
18. Taboret
19. Footstool
20. Sled

Woods

Pine
Oak
Ash
Chestnut
Gumwood
Mahogany
Whitewood
Butternut
Beech
Sycamore

Operations

The following processes will be considered in making the foregoing objects:

1. Measuring
2. Lining
3. Planing
4. Squaring
5. Gaging
6. Sawing
7. Chiseling
8. Boring
9. Gouging
10. Chamfer planing
11. Gluing
12. Nailing
13. Screwing
14. Varnishing
15. Shellacking
16. Scraping
17. Sandpapering
18. Staining
19. Sharpening tools
20. Grinding

EIGHTH YEAR

Projects

1. Serving tray
2. Medicine cabinet
3. Taboret
4. Umbrella rack
5. Clothes rack
6. Picture frame
7. Chair
8. Desk
9. Bookcase
10. Table
11. Telephone stand
12. Telephone chair or stool
13. Revolving bookrack
14. Lawn settee
15. Workbench
16. Wheelbarrow
17. Hall seat
18. Snowshoes
19. Skis
20. Various articles used in science

Also work which involves repairing and "fixing" about the home:

1. Setting glass
2. Mending furniture joints
3. Mending chair backs and seats
4. Repairing pans, etc.
5. Wiring electric bells
6. Making window screens
7. Making piazza gate
8. Making keys from blanks
9. Making chicken coop
10. Making brooder
11. Making incubator

Woods

Pine
Oak
Ash
Gumwood
Chestnut
Butternut
Mahogany
White wood (poplar)
Beech
Sycamore
Black walnut

Operations

Processes will be similar to those of the seventh grade with the following additional:

1. Rabbeting
2. Clamping
3. Doweling
4. Beveling
5. Jointing
6. Soldering
7. Glass setting
8. Wiring
9. Painting
10. Polishing
11. Caning

HOW TO START TRAINING IN A FACTORY

(As developed in the Curtiss Aeroplane Company, Buffalo, New York, but applicable to any industry, by Frank L. Glynn)

Establishment

Survey of plant by
  Conference
    General manager
    Plant manager
    Assistant plant manager
  Breakdown from pay-roll showing relative importance of departments

Organization

Director of training
  Reports to
    General manager as to policies
    Plant manager and assistant as to operation

Location

1. Separate floor space in factory about 60 × 200 feet.

   For the location of such activities as could well be brought together as a separate training unit.
2. Separate floor space in departments, the training for which had best be kept in department.
3. "Tagging" of machine or other shop units for training identification when it is necessary to distribute school throughout department and have instructor circulate.

   Note: This latter method requires even a more definite control by the training director than the other two, as the training identification is likely to be lost and importance become insignificant. This method is least satisfactory and should be resorted to only in exceptional cases.

Equipment

The equipment was transferred from the regular production departments to the training department

Note: At first there is likely to be objection to this on the part of superintendents and foremen, but it can readily be seen that machines and appliances *must be furnished* by them *anyway* under the usual method of breaking in help.

No difficulty, however, of this sort was experienced, as those in the Curtiss Company fostered and helped the establishment of the work in every way.

Departments of training

Note: These fluctuated from week to week according to the needs of the production manager based on development or changes in production.

Each month, however, the employment office furnished the training department with an estimate of the help which would probably be required for the two ensuing months.

This formed a basis for the training department to work on, as to the numbers and kind of training to be emphasized during that period, and resolved itself into the employment office giving the training department an order for help, and the employment manager was only too pleased to coöperate in every way.

The departments which have been operative thus far are:

I. Machine work
  - Screw machine
  - Milling
    - Hand feed
    - Power feed
  - Drilling
    - Single spindle
    - Double spindle
  - Shaper
  - Punch press
  - Lathe

2. Filing
    - Hand
    - Machine
3. Drill grinding
4. Tool crib
5. Cable work
    - Wrapping
    - Splicing
    - Dipping
    - Soldering
6. Sheet metal
    - Riveting
    - Soldering
7. Propeller work
    - Shaping
    - Tipping
        - Brass
        - Copper
    - Linen
8. Acetylene and other gas
    - Welding
    - Brazing
    - Soldering
9. Wood-working
    - Strut work
    - Beam work
    - Panel work
    - Wing float
10. Doping
11. Final wing assembly
12. Sewing
    - Panel covering
    - Power machine

Departmental relations

1. *Employment office*

Kept the training department filled to its capacity, drew the trained people from the training department, placed them on production in the factory for which they were trained, and maintained close daily contact with the training department through exchange of daily reports.

It is necessary for the employment office to *keep the training department* MOVING.

2. *Time-keeping*

The record of attendance, punctuality, and time of all persons in training was reported daily to plant manager and training director by the regular time clerk.

3. *Accounting*

Rendered to the training director a weekly report as to cost of salvage, expense, wages of learners, instruction, supervision and administration.

Note: A sample sheet of weekly report may be found herewith, page 242.

4. *Management*

The training director rendered a daily and weekly report to the management summarizing operation of training department, embodying number received, rejected, promoted, returned, and entire operating cost of department.

Operation

1. *Instructors*

The instructors were preferably those taken from the actual production floor. Experiments were made with persons having had teacher's training and experience in teaching activities closely related to the Curtiss work. They were employed by the training department and first put on production until they were thoroughly familiar with the work, when they were taken over for actual instruction.

It was found that their sense of production was low and that they approached training largely from an academic point of view — that they taught more of the construction of fiber than of parts, and approached the problem as "*getting training and education out of production*," rather than getting "*production out of training*."

It is strongly recommended that the most practical type of person be employed, with factory experience as a background — providing, of course, that he or she is amenable to suggestion, has the proper point of view, personality and ability to not only "*do the job*" but also "*to impart the information*" and eliminate all mystery.

We found no difficulty in finding an *abundance of highly qualified instructors* employed in the various shops on an hourly basis. They were the exceptional persons and occasionally we were mistaken in judgment. For instance, we found that a graduate of a foremost technical college, who was an excellent producer, lacked teaching ability, apparently endeavoring to do the work of ten people instead of having the ten persons do it under instruction. Likewise, another operative was employed as instructor upon the high recommendation of a foreman who wanted to get rid of him and disliked to take him back even as a workman.

These were exceptional cases and were quickly remedied by the selection of other operatives who more than made good.

The difficulty lies not with instructors but with obtaining directors for original layout of plan and organization which can be done in from one to three days, with the later general *direction* left to the production manager of the factory and the *operation* of the training department to the instructors selected from the regular factory force.

2. *The learner*

The learner is taken in from the employment office, taught the activity for which he is best fitted, and promoted to the production floor by the employment office.

It is highly advisable to refer persons of *doubtful physique or health* to the First Aid department for physical examination to be sure that the person is physically adapted to the work for which he would like to be trained.

3. *Length of day*

The length of day is the same as that of the factory itself.

4. *Tools and equipment*

The tools and equipment are identical with those used in the factory itself.

5. *Methods of construction*

The methods of construction and operation are the same as in the factory production.

6. *Product*

Instruction is obtained from the *regular* production of the factory for which the operative is being trained. There should be no preliminary "imitation" or "symbolic" work, although salvage parts may be used to advantage AS A MINIMUM in *extreme cases* for the instruction which is introductory to the training room as in acetylene welding.

Rates

There is a difference between the beginning or "learning period" wage rate, in training department, and the "production" wage rate after promotion.

So long as the learner knows that the wage rate will be increased automatically *upon promotion*, and that *promotion* depends upon "coming up to production," then just so much will the *learning period be shortened* and the "production gait" acquired. This eliminates all need of discipline.

Here again is the importance of the instructor's "*production sense*" intensified.

Every instructor should also be a PACEMAKER.

Personal relations

This caused many adjustments and is of supreme significance to those who contemplate the induction of women into manufacturing.

These relations may be summed up as follows:

1. *Personal supervision*

This required a woman *supervisor* with a *factory* and *production* point of view.

2. *Clothing*

Uniform: It was found that a "two-piece" garment with complete waist was most satisfactory. It can be made in any factory so that trousers button to waist. Trousers should be full and have small elastic bands to fit at top of shoes or ankle, thereby securing a good "hang" instead of turning them up and having them slopping down continually. The waist should have close-fitting neck, which can be turned under and left open or buttoned, and half sleeves. Special sleeves should be provided for welders, brazers, and others engaged in similar operations involving hazard, which may button on short sleeves. By having a two-piece suit it is unnecessary for a woman to furnish her shirt-waist. Immediately this involves *sex suggestion* which *should be eliminated*. The two-piece suit also enables the uniform department *to fit each half of the suit to the girl* instead of *the girl to the suit*.

The first uniform, costing about $3.50, is provided by the company without charge and a replacement made when necessary, but if the employee wants two uniforms at once, then the second one is provided at wholesale cost.

When the employee leaves the service of the company, then a uniform must be returned before the employee receives her employment release slip.

Caps with rubber band (cloth for cooler weather and net for summer) should be furnished with each uniform.

This is a very *important element*, especially for *safety*, as a woman's hair is likely to catch in moving machinery, even a small motor hand drill. Besides, this eliminates much difficulty as the hair may otherwise become loosened and constantly in the way of the individual.

Aprons are provided for such activities as may soil the uniform rapidly or permanently — a rubberoid apron in the machine shop, for instance.

Girls like to wear silk stockings and high-heel shoes or slippers.

The stocking should be of cotton and the shoes have low heels. Otherwise the employee will become greatly fatigued, as the high heel places the body in an unnatural position and one cannot work to advantage standing. This was the cause of many women wanting to change over to a "sitting job."

Wearing of jewelry is not permitted.

3. *Rest-rooms*

Each large department has its rest-room for its employees, with a matron in charge.

Admission is by special pass from the forelady, for proper regulation.

It is best to have several such rooms in a large factory rather than one, as more convenient in an emergency and also preventing a great deal of wandering around the plant which otherwise would develop and cause a waste of time and confusion.

4. *Rest-periods*

Each female employee is allowed a rest-period of not less than fifteen minutes each morning and each afternoon.

5. *Drinking-water*

This is provided by drinking fountains. In the warmer months the water is iced by having the feed pipe coiled in the bottom of ordinary wooden, metal lined boxes in which ice is placed.

6. *Luncheon*

It is the practice of the factories obtaining the best results to serve at least hot soups, tea, coffee, or milk at the lunch hour.

In some cases large restaurants are provided and the lunch hour of the men "staggered" with that of the women so that they eat separately or "staggered" by departments.

In other cases "canteen" stands are found in various sections of the factory where service is given in selling various kinds of food, etc.

It is always best to have one of these for men and another for women.

7. *Safety and sanitation*

A very great percentage of women now entering industry are doing so with little previous factory experience, if any.

Constant attention as to safety and sanitation must be given so as to have the newcomer feel that the medical department or nearby hospital or company physician is a *First Aid* rather than a *Last Aid*.

A scratch from fine wire may cause blood poison equally with a more serious injury.

Every effort must be made to acquaint the girls and women of the large service the First Aid can render.

8. *Sex relations*

In many factories sex difficulties have arisen and tended to decrease production.

If the women are properly inducted into industry through training, properly supervised by a matron on the production floors, properly dressed in a uniform garb, all difficulties automatically disappear.

Capacity

The operating capacity of the entire training department is two hundred and fifty persons at one time. The training will turn over about once a week on an average thus providing trained workers at the rate of 10,000 a year or less as the factory needs.

Contrast this with a condition found in one of our largest plants where the factory needed two thousand trained workers a month and the training department was producing only at the rate of 100 a month.

The Curtiss accomplishment shows that a large comprehensive plan and service is readily feasible if only the factory management insists upon it.

Flexibility

The usual custom and tradition of operation schools as a whole is on an *annual basis* with all instructors contracted for on an annual salary.

These conditions must be entirely forgotten in intensive training of factory workers

The *basic element* in a training department is its *flexibility*. A section for training may operate for one week or two weeks or months. It must be *conditioned upon factory needs*.

This means that the instructor can best be taken from the department for which the training is required and when the quota of trained people is filled, the instructor goes back on the regular production floor and assists not only in production, but also in following up the people trained.

WEEKLY REPORT OF DIRECTOR TO THE PLANT OR GENERAL MANAGEMENT

· (Figures inserted not actual)

Department name	*Weekly total in training*	*Total rejected*	*Total promoted*	*Total returned after promotion*	*Total remaining*	*Total wage*	*Total instruction*	*Gross disbursement for wage and instruction*	*Total production credit*	*Net cost of training*	*Net cost per promotion*
Panel........	128	10	40	1	78	$1980	$110	$2090	$1800	$480	$10.50
Machine......	40	5	25	1	12	600	40	640	400	150	6.00
Acetylene......	12	4	6	0	2	175	35	210	150	60	10.00
Total......	540	61	213	6	276	$8085	$555	$8610	$6320	$1890	$8.87

Indirect expense:	
Administration and supervision....	$70
Clerical and accounting.	60
Timekeeping	20
Despatching	40
Trucking..	15
Janitor.	18
Office expense.	15
Total gross cost....	$8858
Credit for production	6320
Total net cost for week, including wages paid....	$2518

TRAINING COURSES FOR VOCATIONAL TEACHERS

One of the great problems connected with vocational education is the systematic training of a sufficient number of instructors for existing and proposed vocational schools.

A. Types of teachers required in day industrial school.
  1. Shop teacher — to give shop practice.
  2. Technical teacher — to give related trade knowledge for industrial intelligence.
  3. Academic teacher — to give general education.

B. Part-time or continuation school.
  1. Technical teacher.
  2. Shop teacher (sometimes).

C. Evening trade or industrial school.
  1. Shop teacher.
  2. Technical teacher.

(The shop and technical instructors are the teachers that give instruction which directly improves the efficiency of the student in his trade, and are spoken of as vocational teachers. The academic teachers are considered as non-vocational teachers.)

Experience shows that the academic or non-vocational teacher has a definite place in the organization of a full-time day industrial school, but not in the part-time or continuation or evening industrial classes. Pupils in a continuation and evening school have intensely practical aims in attending school, and are not willing to study systematically the ordinary academic subjects. This instruction must be imparted in an incidental way, as the need of it appears, in teaching applied mathematics, applied science, etc.

An analysis of vocational schools shows that any system for the training of teachers must provide for three distinct types: shop teacher, technical teacher, and academic teacher.

A. Qualifications of the shop teacher.
  1. Age, 25–40.
  2. Personality — win the respect of boys.
  3. Trade knowledge — know his trade as fully as a journeyman.
  4. Technical knowledge of his trade — command of drawing, mathematics, and science of his trade.
  5. General education — equivalent to at least an elementary-school graduation.

6. Principles and methods of teaching vocational education — that is, to understand the aim and purpose of his work, and to know how to handle a class in the shop, etc.
7. Ability to train boys to be skilled workers.

B. Qualifications of a technical teacher or teacher of related subjects.

1. Age, 25–40.
2. Personality — win the respect of boys.
3. Trade knowledge — experience and familiarity with the processes of the trade, such as will equip to teach the mathematics, science, or drawing underlying the trade.
4. Technical knowledge — ability to teach the technical subjects by preparation of not less than two years beyond the highest grade he is to teach.
5. General education — equivalent to a high school.
6. Principles and methods of teaching vocational education, so as to understand the aim and purpose of his work and to know how to prepare and conduct classroom work.
7. Ability to apply, in a practical way, technical subjects to trade problems.

C. Qualifications of the academic or non-vocational teacher.

1. Age, 25–40.
2. Personality — win the respect of boys.
3. Trade knowledge:
    - a. Appreciation of conditions and problems of modern industry.
    - b. Knowledge of the more common tools and machines.
    - c. Knowledge of the common trade processes carried on in the school.
    - d. Natural mechanical ability.
    - e. Experience as a wage-earner.
4. Technical knowledge.
    - a. Applied science.
5. General education.
    - a. Normal school or college.
6. Principles and methods of teaching.
    - a. Vocational education (technical subjects).

b. General education.
   (1) English.
   (2) Civics.
   (3) Economics.

7. Ability to organize material and teach the same so as to interest the pupil and as far as possible have it function in the life of the pupil.

Any scheme for the training of teachers should provide facilities for the training before entering the service and for the training of teachers in the service. This means at least an evening course and a day course if possible.

The advantages of the day course are:

1. Efficient training, because the pupil's full time is given.
2. Possible to have considerable practice in all types of vocational schools.

Disadvantages:

1. Only able to reach a few students — mechanics are not willing to give up positions.

The advantages of evening courses:

1. Possible to reach a large number of mechanics without loss of pay to them.
2. Reach teachers already in the service.

Disadvantages:

1. Unable to have practice teaching in the day school.

Therefore the most promising plan for the shop teachers is the evening course. A day course may be provided for the training of technical and academic instructors.

A training course of two years should be provided for shop instructors, evenings; an evening course (two years) for technical and academic teachers, and a day course should also be provided for technical and academic teachers.

TWO YEARS' EVENING TRAINING COURSE FOR TEACHERS

Course for shop instructors.

Principles and methods of teaching vocational subjects	60 hours
Industrial science and mathematics	60 hours
Special methods and practice teaching (shop): Methods in shop instruction are to be given for each separate trade by a practical journeyman of the trade, who is an experienced trade teacher	120 hours

Course for technical instructors.

Principles and methods of teaching vocational subjects .... 60 hours
Industrial science and mathematics .... 60 hours
Special methods and practice teaching:
  Science (shop and applied)
  Mathematics (shop and applied)
  Drawing (shop and applied) .... 120 hours

Course for academic (non-vocational subjects) instructors:

Principles and methods of teaching vocational subjects . . . . . 60 hours
Industrial science. . . 30 hours
Shop visits (different trades to become familiar with tools and appliances) . .. . 30 hours
Special methods and practice teaching:
  English
  Civics
  History...... ... . 60 hours

ENTRANCE REQUIREMENTS TO EVENING TRAINING COURSES

To be admitted to the training course a person must possess the following qualifications:

Shop instructor:

Age — Not less than twenty-five nor more than thirty-five years of age.

Trade experience — A minimum trade experience of eight years, three of which must be equivalent to apprenticeship experience.

Educational qualifications — Graduation from an elementary school or its equivalent.

Personality — Good physical condition and personal characteristics.

Technical instructor:

Age — Not less than twenty-five nor more than thirty-five years of age.

Trade experience — A minimum trade experience of eight years, three of which must be equivalent to apprenticeship experience in one of the trades, under the trade experience of the shop instructor, or a training in a trade, in a technical school, or engineering department of a school that will give the industrial and trade experience which will enable him to teach the related trade subjects in such a way as to meet the needs of (vocational) the worker in the trades taught in the schools of the state or local community.

Educational qualifications — Graduation from a high school, and a technical training in applied mathematics through calculus; applied science through applied mechanics; applied electricity, applied chemistry, and drawing to the extent of two years above the vocational school.

Personality — Good physical condition, and personal characteristics.

Academic instructor:

Age — Not less than twenty-five nor more than thirty-five years.

Technical knowledge — A knowledge of industry and trade as a wage-earner or amateur mechanic.

Educational qualifications — Graduation from a high school, and an academic training which might be represented by two years above the high school.

Teaching experience — Three years' successful experience in teaching above the sixth grade, and special ability in handling retarded pupils. It is absolutely necessary for a teacher to have a genuine interest in mechanical subjects and apprentices.

Personality — Good physical condition and personal characteristics.

DIRECTOR OF INDUSTRIES
Bengal.

PRINCIPLES AND METHODS OF INDUSTRIAL EDUCATION

CHAPTER I

THE VALUE OF INDUSTRIAL EDUCATION

EDUCATION is one of the oldest, if not the oldest, institution responding to human needs. The ideal system of education has always been that which in the highest degree prepares one for the duties of life. This means in a general sense the development of the whole man, the physical, the intellectual, and the moral.

In the early ages education was given in the home, and was an intensely practical education. It was given in an informal manner, while the child was taught the usual methods of supplying the necessities of life, food, clothing, and shelter. Later when religion was organized, a special training for priesthood was introduced, consisting of a purely literary training on philosophy, literature, and science. This training was not provided in the home, but by special teachers, who taught this knowledge in a more or less organized form, and in a very formal manner. Thus we see the early development of the two types of education; the intensely practical, taught in a natural, interesting manner, under the direction of the home, and the purely literary, taught in a very logical and abstract fashion. Later, special teachers gave formal education in law, medicine, etc., and the term "education" was applied to any form of organized knowledge taught by formal methods usually in a building called a school. In order to distinguish between the type of education that trains the mind in general and that which trains for law, medicine, etc., the term "cultural" was applied to the former and "technical" to the latter. These two terms were used for many years. As the educational system became more complicated, with the various kinds of schools, the term "technical" lost its original definition, training directly for a career, and was applied to instruction that dealt with industrial arts. On account of this confusion, the term "technical education" is seldom used to-day in its broader sense. The word "vocational" has taken its place.

To-day we find four great divisions of education: physical, vocational, social, and cultural education. Physical education includes all forms of training and instruction, the controlling purpose of which is to conserve and promote useful development of the body and its capacity. Social education may include all forms of training and instruction designed to make better group living and activities; that is, all moral education, civic education, ethical training, and much of religious instruction. Cultural education includes all forms of education; that is, training and instruction designed to develop valuable cultural interests in such fields as art, literature, science, and history. Social education and cultural education are often considered jointly as "general education" or "liberal education." Vocational education includes all forms of specialized education.

General education aims to develop general intelligence, the power of appreciation in all common fields of utilization, and the ability to use languages, mathematics, scientific methods, etc., without reference to any specific calling; while vocational education has as its aim, to prepare for a specific calling, such as law, medicine, machinist trade, etc.

The occupations that men and women follow, that are productive and lead to self-support, may be grouped into six large classes, namely, the professions, the agricultural pursuits, commercial pursuits, trades and industries, and homemaking and nautical pursuits. The divisions of vocational corresponding to the above occupations may be divided into these divisions: professional education, vocational commercial education, vocational agricultural education, vocational industrial education, and vocational home-making and nautical education.

Industrial education denotes the field of vocational education designed to meet the needs of the manual wage-earner n the trades and industries, and in the home. This education is given to persons over fourteen years of age. It is true hat certain forms of hand-training, given to persons under ourteen years of age, may contribute to industrial efficiency; evertheless it is not considered as specific trade training.[1]

This volume will deal with the principles and methods of eaching involved in vocational industrial education; that s, the form of vocational education that prepares the individual specifically for some industrial pursuit or trade, uch as a machinist, millwright, etc.

The different forms of hand-work given in the first six rades to boys and girls, paper-folding, picture-mounting, lay-modeling, whittling, weaving, needlework, and other onstructive activities within the range of the experience of hildren under twelve years of age, are called "manual ts." The form of training and instruction, usually in wood d metal, sometimes printing and bookbinding, for boys tween the ages of twelve and eighteen, is called "manual aining." Corresponding to manual training for boys, a urse called "household arts," "domestic economy," or ome economics," is provided, in some schools, for girls tween the ages of twelve and eighteen. The course conts of a variety of practical exercises and experiences in cooking and sewing, to give some practice and an insight into domestic operations. The above forms of education, manual and household arts training, are part of general education, and are provided to make pupils appreciate the value of industrial and domestic life.

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[1] See page 181.

At the age of twelve, about the sixth grade, a program of instruction and training is offered, to children who are not profiting by the regular course of instruction and are not going to college, to participate in a series of practical experiences relating to many vocations. This is not vocational education, but prevocational education, and assists pupils to sample different trade experiences, so that it will be possible for them to make an intelligent choice of occupation. Vocational guidance is a form of instruction and examination to present trade information and guidance to pupils over twelve years of age.

The conclusions from a number of surveys show that the great bulk of boys and girls leave school as soon as the law allows, usually at the age of fourteen, before completing the elementary course. This army of children is four times as large as the group which at approximately the same age enters the high school. About one of every six of these children has reached the eighth grade, one in every four has attained the seventh grade, and one out of every two, the sixth grade.

These pupils experience very little difficulty in obtaining work at a high initial wage in so-called "blind-alley" employments; that is, a work that requires little training and involves little thinking. Another important point is, that these pupils are very restless, drift from one occupation to another, and are idle approximately one half of the time. The so-called "skilled trades," such as the higher branches of metal and machine trades, the building and printing trades, do not care to receive children under sixteen years of age, because they have not the physical development to do consecutive or accurate work and require considerable supervision. Very few of the present elementary, and practically none of the evening schools, show any great assistance to this group of young people, in the training, discovery, guidance, and development of their capacities or preparation for the work they might or do enter. It is from this group that industry recruits its workers.

A very high percentage of the skilled workmen, foremen, and superintendents of industries and trades of this country to-day have been educated across the water, while the American boys occupy the ordinary clerical, mercantile, and a number of unskilled positions, at hardly a living wage. Whatever preparation the public school system is providing, for the training and development of young people for the work they are to enter, is given in the high school, where about three per cent of the pupils are found, and less than one per cent of those ever go into the industries as mechanics.

The progressive development of all trades and industries demands the training of a group of skilled workers who may act later as foremen. The future skilled workers must be trained. Industrial conditions to-day differ very greatly from those of earlier times. For example, trade and industry are more ambitious, more successful, and more scientific, han ever before. They have content that is worthy of study for itself. Years ago they were too simple for intelectual study. Now they require the highest form of mental study and demand the best intellects.

A glance through educational history will show us that he reason industry has not received a dignified place in the ourse of study of the public school system is due to the traition from the Greek philosophers, who looked with conempt on manual work which was performed by slaves, orkers, and tradesmen of the age, and purposely omitted from the schools any training along the line of utilitarian subjects. During the Middle Ages the same feeling existed; industrial education was apart from culture; one was a matter of apprenticeship and the other a matter of books. This state of affairs continued in England up to the nineteenth century, when the primary school provided the education for the industrial workers. Pupils were educated in the higher schools to be employers. People were expected to remain or continue in their station of life. Culture was the possession of the upper classes and had absolutely nothing to do with utility. During the last century the sentiment that the masses were expected to support the classes in their leisure, particularly in America, has passed away. The spirit of democracy has dominated our social system, so that to-day every man is expected to be a worker.

Vocational industrial education or industrial education may be justified on the grounds that a democracy means equal opportunities for all, that every one should be engaged in a useful occupation within reasonable bounds of age, health, and strength; that is, all persons of both sexes, not incapacitated or in school, should be working. Practically eighty-five per cent of the present workers — those who work for pay — are engaged in producing concrete material; about five per cent are engaged in professional service; the other ten per cent are in various forms of personal service. Life and health, and to a large extent discipline and character, must be derived from employment in the industrial and commercial fields. Any large number of men and women without training for some definite occupation, and not able to be producers, are apt to become a heavy burden on society, and often form a discontented class that threatens the existence of our Government. Society must provide means and training for the proper distribution of human talent, in order that every member may be assured of a living wage or salary, Industrial education may be advocated because of the increased earning power it affords. The salary of a person may be determined by certain factors which may be divided into two groups, the individual and the organization. The individual group includes such factors as natural ability, proper development of the body, the development of honesty and morality, which are by-educational products of general education and industrial education. The factors that enter into the organization group are capital, up-to-date appliances, leadership, proper allowance for depreciation, etc. One of the chief factors that will increase the productivity of the individual is industrial education. Increased productivity means that the country as a whole will be able to increase the standards of living and the worker will be able to have some of the luxuries.

To summarize: It is in the interest of society, labor, and capital to have the most effective system of industrial education. Properly trained workers (labor) increase the production. From the workers' point of view physical energy and knowledge represent the workers' capital, and the greatest return to the worker, in addition to personal satisfaction, comes only through an efficient system of industrial education. Society profits when every member has rendered his greatest contribution.

QUESTIONS FOR DISCUSSION

1. What was the principal aim of formal education in the early ages in (*a*) Rome; (*b*) Athens; (*c*) Middle Ages; (*d*) United States, to-day?
2. What caused the change of the aim of formal education during the different periods?
3. State the division of education that each one of the following subjects represents:
   (*a*) Manual training in the sixth grade.
   (*b*) Military drill in a high school.
   (*c*) Recreation in an evening high school.
   (*d*) Forging in a technical high school.

(*e*) First-year science.
(*f*) French in a classical high school
(*g*) Civics in a community center.
(*h*) Roof-framing for house carpenters in an evening trade school.

4. What is the distinct meaning to-day of "technical education"?
5. What is the meaning of the term "vocational education" to-day?
6. What is the distinct meaning of "industrial education" to-day?
7. Name the class of education to which each of the following occupations belong:

(*a*) Sea pilot.	(*e*) Dentist.
(*b*) Die-sinker.	(*f*) A housewife.
(*c*) Market-gardener.	(*g*) A chemist.
(*d*) Stenographer.	(*h*) An expert accountant.

8. What is the meaning of "industrial efficiency"?
9. What is a "blind-alley" employment? Give a list of such employments.
10. What is a "producer," "consumer," and "non-producer" in an economic sense? Give an example of each.
11. Trace the stages of development of a steel boiler plate from the time it leaves the ground to the time it is installed as a boiler. Explain in terms of economics

LIST OF REFERENCES FOR FURTHER READING

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(A description of the trades and industries in New York State showing the educational needs of each one.)

Laggards in Our Schools. Leonard P. Ayres.

(Statistics showing the large percentage of pupils who repeat grade work and leave school as soon as the law allows them.)

"Economic Reasons for Vocational Education." J. F. Scott. *Pedagogical Sem.*, June, 1919.

(Reasons for vocational education based on economics.)

CHAPTER II

THE EDUCATIONAL NEEDS OF TRADES AND INDUSTRIES

SINCE industrial education is to train specifically for definite positions in the trades and industries, it is clear that to be effective it must function with their needs. The modern organization of industries and trades tends toward the uses of labor-saving devices and power machinery. This means a tendency toward standardization and specialization of products, which involve a large organization under one roof and one manager for purposes of economy. Every organization is divided into two departments: production (manufacturing) and the distribution (selling) phases. The production is carried on by an organization varying from a large to a small scale, composed of a manager, agent, or superintendent, overseers or foremen, section or second hands, and workers. The large establishments have in addition designers or draftsmen, testers or chemists, shop supervisors, and sometimes research engineers.

The manager or superintendent may or may not come from the ranks. In the past it has been possible for men lacking technical training, but possessing good common sense and business capacity, to rise to this position. This is not true to-day in a great many engineering establishments and large factories. Oftentimes he is a technically trained man who entered the industry direct from school as an assistant to the manager or superintendent. A manager or superintendent must have a great deal of foresight and will power. He must have initiative, an analytical mind, and executive ability; that is, he must be able to see clearly a problem, its solution, and have the ability to put the solution into effect.

The progress of industries in the past has been due to the efforts of scattered inventors and workmen all laboring under great disadvantages. Manufacturers and tradesmen are beginning to see that there are numerous possibilities of applying different scientific discoveries that have taken place. Competition compels us to realise that all industries and trades have developed to a point where the working-out of theory and practice has become a science, and that the application supersedes the old "rule-of-thumb" method and demands the continuous employment of scientifically trained leaders in a bureau of research. The results of this bureau will tend to lower the cost of production by eliminating manufactory weaknesses, improving tools, and applying the principles of science to raw materials, waste products, methods, etc. It is for this reason that large corporations such as the General Electric Company have a research staff with a group of specialists working on new industrial problems. The group may include chemists, biologists, designers, metallurgists, mechanicians, etc., who have been trained in the scientific departments of the colleges.

A foreman usually comes from the ranks of workers. He is the job master, and as such must be able to get good work out of men. This means he must have good judgment of human values, handling men. In addition his outlook on life will be very different from that of the worker. He must have a habitual reaction to human reaction.

The skilled worker should have, in addition to a good physique, a clear mind capable of keen perception, and an inventive mind, which is often called ingenuity. The keen sense-perception should be such as to do very accurate work, dealing with measurements of a thousandth part of an inch. The skilled worker differs from the unskilled worker in the degree of mental versatility. He has acquired by experience a fund of information and skill so that he is able to form new judgments. The experience of the skilled worker is such that only recent trade experiences are available for ready recall. This is the principal reason why a skilled workman cannot leave his trade for any length of time without suffering a loss of skill.

Semi-skilled workers or machine tenders, etc., should have a good physical development and quick time-perception, which is really the ability of being dexterous. Oftentimes they are physically sluggish, in addition to the general characteristic of slow mentality which may be due to the lack of good nutritious food or dissipation, or both. Any reflective action on the part of the semi-skilled worker retards his rate of production. These workers are generally recruited from the ranks of those who leave school, follow a line of employment with no prospects until they reach manhood, and then see a chance of getting an adult wage without going through the training necessary for the skilled positions. The worker is seldom called upon to meet a new situation, and his work never involves problems which cannot be solved from the limited range of his past experiences. This automatic and semi-automatic machinery develops a fatigue, which is a serious problem. Women are able to work in this way better than men, and do not show fatigue to as great an extent.

The unskilled class of workers usually represents the least intelligent part of the community. Of course there are exceptions, as in the case of bright young people who have become "blind-alley" workers or others who lack the sense of responsibility. In spite of the great increase in inventions, there are a great many processes performed by unskilled labor.

The occupations found in trades and industries may be roughly divided into the following groups:

Occupations requiring skill and trade knowledge.
Occupations requiring skill and no trade knowledge.
Occupations requiring trade knowledge and no skill.
Occupations requiring neither skill nor trade knowledge, except in a very low degree.

There is a certain amount of industrial training that must be imparted to the group of men on the distributing phase of industry. The knowledge of the salesman of his product should be thorough, and at the same time should be very different from that of the mechanic.[1]

A great many men and boys are injured and many die every year on account of injuries or the conditions under which they work. Experiments and careful questioning of injured people seem to indicate that most hand injuries are due to performing work on machines automatically, and because, without the intellect, the hand has no sense of danger until just at the instant the injury takes place. The assumption is that the hand proceeds automatically to correct the machines when they become jammed or caught, and unless the intellect becomes active, the hand is endangered and caught. The inclination of the workman to perform his tasks automatically has caused nearly all industrial accidents. If employees worked with their intellects fully concentrated upon their work, guards would not be necessary, for workmen would be awake to all dangers at all times. In many lines of work this concentration would cut down production more than fifty per cent. If the workman had to think of every move of his hand before acting he could not do more than half of his work. Therefore machinery must be both guarded and production decreased in order to obtain best results. A great many accidents and industrial diseases may be prevented by care, safety devices, and proper safeguards for the health of the worker. A specially trained expert called a "safety engineer" is usually employed to look after the welfare of the men and boys, teaching them how to avoid accidents and to prevent disease.

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[1] See page 207.

Every year many workers are released from the trades and industries on account of injuries received. These men and boys are often allowed to remain idle for the rest of their lives. Very carefully prepared devices called "working arms" and "working legs" have been invented for injured men, to assist them in performing certain lines of work. In many cases the earning power of the injured worker has equaled that of the normal man.

One of the most serious problems to-day that confronts the industrial world is the discontent and unrest of the workers of the trades and industries. This is due in a measure to the overgrowth of the present industrial conditions of highly specialized work that has made the worker a mere attachment of a machine. Modern engineering has developed the machine part of industry at the expense of the human factor. To illustrate: Modern shop systems in general have been organized so as to allow to each machine a definite earning capacity that is expressed in the form of a daily or hourly machine rate. Machines represent the investment of large sums of money, and therefore must be kept at work all of the time in order to justify the expenditure involved in their purchase. If a machine, for any reason, is allowed to stand idle, the charge against it mounts up, and it becomes a burden instead of being a useful and productive investment. In the attempt to develop the efficiency of the machines, many manufacturers and tradesmen have lost sight of the fact that the worker is human and demands consideration.

The progressive manufacturers have seen this spirit of unrest growing among the employees and have attempted to assist them in various ways which are usually grouped under a heading called, "welfare work." A specially trained person called an employment manager is usually selected to employ workers and look after their welfare. This welfare work has failed in some cases because it conferred benefits upon a group of workmen, requiring and asking no service on their part. Experience shows that the average American workman is suspicious of an employer "bearing gifts." This same average American workman, however, is keen enough to engage coöperatively in any undertaking that is frankly advanced by the employer as of mutual advantage, as the establishment of an all-comprehensive employees' service department, such as locker-room service, physical examinations, dispensary dental service, sickness and death benefits, lunch-room service, banking and loan service, industrial education, and recreational facilities.

This coöperation will tend to develop a strong sense of loyalty between the worker and the organization, an *esprit de corps* similar to that existing between the apprentice and master, and to remove discontent among the workers. The average manufacturer seldom knows or sees his men, and therefore is not able to have the sympathetic understanding that he should.

Another great educational need is the training of the immigrant. The United States is just beginning to realize the great educational task before it, the education of at least thirteen million foreign-born people in this country, many of whom do not speak our language, do not come in contact with Americanizing influences, and are in a measure out of sympathy with the country's institutions. Heretofore we have looked to the traditional school system, the influence of social contact, and city life to mould the recent immigrant and his children into American citizens. These different agencies performed this work when the numbers of immigrants were not large, and were from Ireland, Scotland;

England, Sweden, etc., people who were more or less familiar with the institutions of this country. Within the last decade or two the numbers of immigrants have greatly increased, and many are from the remote sections of Europe, making the problem of assimilation greater than ever before.

The industries of this country are employing these immigrants to perform highly specialized, semi-skilled, and unskilled work. In iron and steel manufacturing east of the Mississippi River 57.7 per cent of the employees are foreign-born; in bituminous coal mining in Pennsylvania, Ohio, Indiana, Illinois, Kansas, Oklahoma, Arkansas, Alabama, Virginia, and West Virginia, 61.9 per cent of the employees are foreign-born; in woolen and worsted manufacturing in the North Atlantic States, 61.9 are again foreign-born; in clothing manufacture in New York City, Rochester, Baltimore, and Chicago, 72.2 per cent are foreign-born; and so on. Probably two thirds of the construction and maintenance work of the railroads and railways has been done by the foreign-born workman. In addition most of the general street and road construction has also been carried on by the recent immigrants.[1]

An examination of the work performed by these people shows that it is not educational. They are in the employer's hands from eight to twelve hours a day, and when they get through with the day's work they are too tired to receive definite instruction for Americanization.

QUESTIONS FOR DISCUSSION

1. Draw a diagram showing the organization of
   (a) Cotton mill.
   (b) A large electrical plant.
   (c) General machine shop.
2. What are the qualities necessary to be a research chemist in a rubber factory?

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[1] Report on the Education of the Immigrant, U.S. Bureau of Education,

3. What are the qualities necessary to be a high-grade die-sinker?
4. Why cannot young men between the ages of 14 and 20 be classified as to their future ability to serve as foremen?
5. What callings in industrial trades lie between the professional engineer and the skilled tradesman?
6. What are the qualities necessary for a man to be a foreman of a machine shop?
7. What are the qualities that distinguish a lathe hand from one who sells lathes?
8. What are the qualities necessary for a man to be a general manager of a large electrical plant employing 6000 hands?
9. What are the necessary qualities to become a good draftsman in a shipyard?
10. Name the trades and industries that require a large number of unskilled workers
11. Should industrial education be given to the group mentioned in question 10?
12. What are the economic advantages of a highly specialized trade?
13. Is there any tendency to limit the differentiation and specialization that is going on in the trades and industries?
14. Name some occupations that cannot be entered during youth
15. Name occupations that depend upon juvenile help
16. Is there any place in the trades and industries for a so-called "handy man with tools."

LIST OF REFERENCE MATERIAL FOR FUTURE READING

* *The Modern Factory* George M. Price

(The organization of a factory showing the different classes of workers.)

* *Education for Industrial Workers* Herman Schneider

(A very interesting study of the work performed by the different classes of workers.)

* "Business Men in the Making." F. M. White. *Outlook*, Aug. 26, 1911.

* *Practical Safety Methods and Devices.* George A. Cowee

(Need of practical safety methods to protect the workers.)

Workers and the State A. A. Dean.

(A system of industrial education is as necessary as professional education.)

* *Betterment, Individual, Social and Industrial.* E. Cook.

(Methods to improve the working classes.)

** *The Spirit of Youth and Industry* Jane Addams.

(The relation between the habits of youth and the needs of industry.)

CHAPTER III

HOW MEN HAVE BEEN TRAINED FOR TRADES AND INDUSTRIES IN THE PAST

THE history of the training of young people for the trades and industries in the past will assist us materially in solving the same problem to-day. Of course we must bear in mind that we cannot transplant any of the institutions of the past and expect them to meet the problems of to-day, because conditions of the past and the present are very different.

As far back as the time of the Roman Empire men were selected to build and destroy bridges, water-supplies, and fortifications. Every well-organized army had its group of bridge-builders, etc., called "engineers." Later they laid out campaigns, made plans to defend or attack forts. In order to do this work they invented implements of war, engines, etc. In time of peace they constructed waterworks. When the duty of constructing roads, waterworks, arches, etc., was left to the civil authorities, the expert was called a "civil engineer," to be distinguished from the "military engineer." Later experts on the steam engine were called "mechanical engineers." In like manner the term "electrical engineer," "sanitary engineer," "mining engineer," etc., arose. Engineers in England at first received their knowledge through the world of experience aided by advice from older men. As time went on opportunity was provided for the training of engineers by means of an apprenticeship of seven years to an old established engineer. The fee usually paid depended upon the reputation of the engineer. Most of the practical training was received through experience in the field, and the theoretical and scientific knowledge was imparted by the engineer in the office two or three months of the year.

The skilled mechanic requiring less theoretical instruction and more manipulative skill than the engineer has always, up to a generation ago, been trained in either the home or the shop, under the guidance of his father or a skilled mechanic or master. In order to show how this training has been given at different times in the world's history, we may divide the history of the industrial work into four stages or periods: first, the family system; second, the guild system; third, the domestic system; and fourth, the factory.

Under the family system the different forms of industrial work were carried on by members of the household for the purpose of meeting the needs of the family. There were no sales of the product. Each class in society, from the peasant to that of the nobleman, had its own devices for carrying on all phases of industrial work. Father taught son all forms of manual work, and mother taught daughter to perform the household duties. The manual and household work of the nobility were performed by slaves.

As communities became larger and cities sprang up, all forms of trade became more than a family concern. There was a demand for a better grade of industrial products. This meant a larger supply of hand tools than was usually found in the home of the ordinary worker. Some workmen began to develop greater ability in commercializing their handicraft products than others, and became prosperous. The smaller mechanic who owned and constructed all his own tools found that he could not compete, so he started to work for the more prosperous mechanic in a shop rather than a cottage. As time went on each manufacturer developed a reputation, and usually employed several workmen and some young men to learn. The manufacturers became quite important, and soon grouped themselves together under an organization, called a "guild," and applied to the city for certain privileges. After a while each group of tradesmen, such as cloth workers, etc., organized under a distinct guild, carried on by a small group of men called "masters," employing three or four men (distinguished later as "journeymen"), and at least one beginner called an "apprentice." The guilds organized and dominated all conditions of the manufacturer.

The masters, under the guild, had the advantage of combining together and obtaining the monopoly of the trade in the local market, instead of competing against one another. After developing the trade conditions of the craft, they naturally turned to the question of training workmen, that they might have a standard of workmanship. A young man was obliged to serve an apprenticeship of seven years before he was allowed to become a journeyman. These are the conditions we find existing in the trades of England during the fourteenth, fifteenth, and sixteenth centuries.

The guilds set up very definite standards for the training of apprentices. The youth was taught all branches of the trade. The shops were small, and masters and apprentices often worked at the same benches, side by side. The master worked at all processes of the trade and taught the apprentice the complete trade. Since the number of apprentices was restricted to the number of journeymen, there was little division of labor. The apprentice assisted the master at every process of the trade. The seven-year apprenticeship gave the youth the training necessary to bring out the artistic side. The desire of the apprentice to become a master some day was the incentive for him to acquire a knowledge of all the processes of his trade, dexterity of hand, and artistic skill. The efficiency of the apprenticeship was guarded by guild supervisors. Both master and apprentice were members of the same guild. Guilds regulated conduct and specified what should be taught.

In the beginning the training was merely one of development of skill, and consisted of theory of materials used (gained by working on them) and the acquisition of experience and knowledge handed down and guarded zealously by older craftsmen. Scientific knowledge of the industry at this time was very limited.

The careful, individual attention, on account of the small number of apprentices, given by the journeyman to each young man, prevented him from being superficial. The master's and journeyman's work furnished the model for the youth to imitate. Since the earnings of the apprentice went to his master, the young man found his reward, not in immediate gains, which tends to superficiality, but in his employer's praise and in the joy of artistic creation.

The apprentice was taught by actual participation in trade work, by imitation, supplemented by suggestions, and the necessary information. Comenius, in the seventeenth century, reminds teachers that artisans do not detain their apprentices with theories, but set them to do actual work at an early stage; thus they learn to forge by forging, to paint by painting, to carve by carving, etc. Mechanics do not begin by drumming rules into their apprentices. They are taken into the workshop and shown the work that has been done. When the boy wishes to imitate this work, tools are placed in his hands, and he is shown how they should be held and how to use them. If mistakes are made, the mechanic gives advice and corrects them more often by example than by mere words, and as facts show, the novices easily succeed by imitation. Obadiah Walker in his work, *Of Education*, says, "In manual arts the master first showeth his apprentice what he is to do, next works it himself, in his presence, next gives rules, and then sets him to work."

The master craftsman taught and arranged his trade skill and information in a way different from the logical order of the arts and sciences as presented to-day by the schoolmaster. As each journeyman was not allowed to have more than two apprentices, the instruction was individual to a certain extent. The master craftsman began his instruction by using the strong instinct, imitation, and proceeded to teach manipulative skill through it. The related trade knowledge included much practical information on the arts and sciences, and was imparted to him as necessary, in such a way that the apprentice first had the practice, and then the theory or the thinking about the practice. Under this system skill was acquired intelligently. The apprentice practiced commercial work. If he required any additional drill on certain details, he would repeat the operation (drill) on some waste stock. Note that the apprentice was not taught exercises, but his skill was acquired in the most economical way, by learning all the habits of skill in the complete project, so that each had its proper setting. A motive for doing the work was shown the apprentice the first day, when an actual model that had commercial value was shown. The young man was not asked to perform a series of operations, given by the master, through unthinking imitation, without any regard to the purpose of the work.

Apprentices lived with the masters, and in this way were imbued with the work, the industrial atmosphere and features of the trade which were handed down from father to son. In addition a distinct spirit of coöperation existed among the master workmen and apprentices that is lacking to-day between the employer and his employees. This close relation between master and workmen of the old-time trades prevented a great many of the disagreeable relations that exist to-day under our present industrial system.

By the middle of the eighteenth century the trades began to break away from the guilds and to spread from cities to rural districts. The work was still carried on in the master's house, although he had lost the economic independence he had under the old guild system, where he acted as merchant and manufacturer. He now received materials from the merchant and disposed of the finished goods to a middleman who looked after the demands of the factory. It was the family system that existed in the American colonies at the beginning of the settlement, followed by the domestic system. The guild system was not adopted in the United States, as it was going out of existence on the Continent during the settlement of the colonies.

During the early colonial times boys and girls were trained by a well-defined apprenticeship in the shop and office, really handed down from the guilds, and by a training on the farm and in the household. The practical education of the child on the farm often began as early as six years of age, when he or she assisted in doing some of the little chores. The work was carried out in the spirit of play, and it was varied and interesting. Thus we see the old-fashioned mother training the child into habits of work and the enjoyment of the same, by bringing play and work together. The play furnished an adequate physical training for the child. It was better than the gymnastics of to-day because the body was best exercised in the accomplishment of some purpose. Young people, through the agencies of the home, shop, and community, were trained in the useful habits, thrift and temperance, to have respect for law and order and in the development of the higher types of citizenship.

The characteristics of young people are the same to-day as when the old-fashioned apprenticeship system existed. The training on the farm, in the home, and the apprenticeship in the shop held the strong young people, corresponding to the same type of to-day, during the long period of adolescence, and gave them the necessary training to become good tradesmen and housewives and successful men and women.

Let us examine very closely the apprenticeship in the shop to-day, the training in the home, and the methods of teaching. If we examine the different industries to-day, we shall find that the training and skill necessary to perform the work vary. The greatest training is required in industries demanding a high degree of skill and intelligence, and the least in those highly specialized occupations performed by the newly arrived immigrants from the agricultural districts of Europe. In the machine, engine, and locomotive construction works, where the trades demand a high degree of skill and intelligence, there is need of broadly equipped workmen of high technical skill. On the other hand, in the case of those factories employing workers tending semi-automatic tools, where a low grade of skill and intelligence is required, very little industrial education is necessary. To illustrate: the rolling mills require a few skilled hands who direct the operations, and a great many unskilled hands who assist and tend machines. In the manufacture of sheet metal and electrical apparatus, where the work is performed by semi-automatic machines, the operators simply feed the machines which requires little mental effort after the first week. Jewelry and gas fixtures are made by piece workers, who perform highly specialized work and are trained for it. All-around skilled help is necessary for the finer class of work.

The old-fashioned apprenticeship was a very satisfactory method as long as the master had time to teach the apprentice and the apprentice had time to learn all about his trade. A scientific advance has revolutionized industrial and economic conditions of old times. The factory system, of a highly specialized character, and the modern application on a large scale of machines and capital to manufacture, have taken place. The master has become so busy trying to maintain himself against the competition of others, and to keep up with the technical advancement of his trade, that time has failed him for the instruction of his apprentice, while on the other hand, the latter has found that the trade has developed to such an extent that he can no longer learn its fundamentals by mere activity in his master's shop.

Thus the apprentice, no longer a pupil, has to-day become merely a hired boy, who, while making himself useful around the workshop, learns what he can by observation and practice. If he sees the interior of his master's home, it is to do some work in no way connected with his trade. In olden times the master worked with his men; now he rarely works at his trade; his time is spent more profitably, in seeking for customers, purchasing material, or managing his finances. The workshop is put in charge of a foreman whose reputation and wages depend on the amount of satisfactory work that he can produce at the least cost. He has no time to teach boys, and as there is little profit in the skilled trades for boys between the ages of fourteen and sixteen, they are not wanted. The unskilled trades thrive on juvenile labor. It is true that in Europe the seven-year apprenticeship still exists to some extent, and a more thorough training is provided for apprentices than in this country. The old apprenticeship is not likely to be revived. A new system of practical education and training must take its place.

The industrial operations of a factory are so highly specialized that the operators are not obliged to exercise any of the academic training received in school. The result is that they rapidly lose the habit of thinking, the power of initiative, and when they reach the age of manhood are not so well educated as when they left school. Not only that, but when an opportunity presents itself, we find our American young people are not able to fill responsible positions, such as overseers or heads of departments, which are filled by skilled workmen from Europe who have received a complete training, practice, and theory, in the mills or shops during the years from fourteen to eighteen — while they were working.

QUESTIONS FOR DISCUSSION

1. What objection may be raised to-day to the method of training a mechanical engineer by apprenticing the student to a practicing mechanical engineer?
2. What is the difference between the pure arts and sciences and the applied arts and sciences?
3. Explain why the growth of technical schools in this country did not take place prior to the nineteenth century.
4. State the conditions under which the family system existed.
5. Why was the guild system a necessary economic condition?
6. Organizations bearing the name of cloth workers' guilds are found in certain parts of England. Explain the meaning of the name.
7. Explain the causes that led to the downfall of the guilds.
8. Explain why the domestic and not the guild system was introduced into this country.
9. What are the economic advantages and disadvantages of the old-fashioned apprenticeship in a small shop under a master and several journeymen.
10. Explain why the old-fashioned apprenticeship of seven years will never return.
11. What is the length of the apprenticeship in England to-day for an apprentice dyer?

LIST OF REFERENCE MATERIAL FOR FUTURE READING

* *A History of Commerce and Industry.* Cheesman A. Herrick.
(The essentials of history from the commercial and industrial point of view.)

* *Studies in the Evolution of Industrial Society.* Richard T. Ely.
(A general survey of industrial society and its evolution into present conditions.)

** *Industrial America.* J. L. Laughlin.
(A discussion of the general industrial situation in America.)

* *Evolution of the Training of the Worker in Industry.* C. A. Prosser. National Education Association. Proceedings, 1913.
(A discussion of the training of the worker.)

** *The Apprenticeship System in its Relation to Industrial Education.* Bulletin United States Bureau of Education. 1908.

* *Apprenticeship in American Trade Unions.* J. M. Motley.
(A description of apprenticeship regulated by trade unions.)

* *Value of a Thorough Apprenticeship to the Wage-Earner.* W. B. Prescott. National Society for the Promotion of Industrial Education. Proceedings, January, 1908.
(A description of the apprentice training to-day.)

* *Trade Instruction in Large Establishments.* J. F. Deems. National Society for the Promotion of Industrial Education. Proceedings, January, 1908.
(A plan of trade instruction in a large railroad.)

** *English Apprenticeship and Child Labor.* O. J. Dunlop. Studies in Economics and Political Science issued by the London School of Economics, No. 20.
(The difficulties between the English apprenticeship and child labor.)

CHAPTER IV

DIFFERENT TYPES OF INDUSTRIAL SCHOOLS

There are many types of industrial schools to meet the varied needs of industries and trades; the college grade or school of technology, the secondary industrial, part-time industrial, continuation-day industrial, trade schools, and corporation schools.

A close examination of educational history will show us that we usually begin at the top of the ladder and work downward. This is due to the fact that the old system of education believed in educating a few minds to act as leaders and leave the masses uneducated. It was for this reason that universities preceded the common schools, and schools of technology preceded trade schools.

While science had been introduced into some of the colleges long before the nineteenth century, it was not until then that a systematic study of the applications of scientific discoveries to the practical affairs of every-day life was carried out by the establishment of the Royal Institute in London by Count Rumford. The aim of this institution was "the general diffusion of the knowledge of all men and useful improvements, and teaching the application." It contained workshops for blacksmiths, with forge and bellows, all sorts of models of machinery, and a score of mechanics. It grew into a higher institution, and became a great laboratory for the research of pure science.

The United States did not establish technical schools for the training of engineers until the early part of the nineteenth century. About this time the States were beginning to become thickly settled, and it was necessary to build rivers and canals and to employ foreign experts and engineers from France. There was a great demand for our young men to become engineers, and some were sent to France to be educated. In order to meet this educational need a school of theoretical and applied science was founded at Troy, New York, in 1824.

About the middle of the nineteenth century chemistry, physics, and geology had become very important sciences, and the colleges established departments for the teaching of each. The influence of the old course of study was such that these new subjects had not the same dignity, and were set aside in a separate school, as, the Sheffield Scientific School at Yale, the Lawrence Scientific School at Harvard, and the Chandler Scientific School at Dartmouth. At first these were schools of pure science, but later became engineering schools.

In 1862 the United States, in spite of the fact that it was in the midst of the Civil War, realized the necessity for action. Congress in that year passed an act granting to each State thirty thousand acres of public lands or their equivalent, the income therefrom to be appropriated "to the endowment, support, and maintenance of at least one college where the leading object shall be, to teach such branches of learning as are related to agriculture and the mechanic arts, in order to promote the liberal and practical education of the industrial classes in the several pursuits and professions of life." Surely a noble object, and one which Congress has striven ever since to advance.

About fifty years ago the Massachusetts Institute of Technology was founded "for the purpose of instituting and maintaining a school of industrial science, and aiding generally, by suitable means, the advancement, development, and practical application of science in connection with arts, agriculture, manufactures, and commerce." From the beginning this institution has received aid from State and Nation. The Institute of Technology dealt and still deals with the most advanced workers, as is true of the Lawrence Scientific School, the Worcester Polytechnic, and other schools of the same type in the United States.

England, while contributing more than any other country to scientific discoveries upon which technology is based, did not adopt technical education until 1881, when it was seen that the high place in engineering and manufacturing skill that England occupied was threatened by the Continental countries. The increased skill of the people on the Continent was due in no small degree to the encouragement the Governments gave to schools of technology.

The City and Guilds of London Institute for the Advancement of Technical Education is one of the institutions established by the English Government to develop technical skill in her engineering and manufacturing industries. It includes in its management the operation of three London colleges and a system of technological examination.

The aim of the college grade school of technology is to provide a four-year course of study that will train men and women to become mechanical engineers, research chemists, designers, etc. The first two years comprise a general technical training, with cultural studies, and the last two years specialization in one department.[1]

The training provided at present in our engineering schools of college grade is a splendid training for the expert and chief engineer. Fully ninety per cent of the men employed in responsible positions in engineering do not require as complete an education as these schools give. A great deal of work done in engineering offices is of a nature that requires a fair knowledge of the standards of construction. In manufacturing plants most of the work has been standardized, and is repeated day after day, or year after year, so that much of the work of preparing boys for ninety per cent of the positions in the engineering works can be performed by a school with a two-year course. Pratt Institute of Brooklyn, New York, and the Wentworth Institute of Boston, Massachusetts, give a two-year course in technology.

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[1] See page 201 for course of study.

Up to a few years ago, almost all of the institutions in this country that provided industrial education aimed to be of a collegiate rank. They provided a training for students over sixteen or seventeen years of age who had had a high-school education or its equivalent. Often the same courses were provided for evening instruction for those at work during the day. The education received in these schools was the highest possible training in the useful arts. This education and training often exceeded the real educational needs of the responsible positions in commercial and industrial life. Little if any effort was made by those schools to supply technical education of a secondary grade; that is, a simpler technical education to the great mass of young people between fourteen and seventeen years of age who desire a practical education.

This one-sided educational scheme was due to the tradition that one must have a cultural before a technical education, and to the circumstance that at the time of the origin of the technical schools they were patterned after the existing colleges.

In 1876 the European Manual Training Exhibits at the Centennial Exhibition attracted the attention of a great many thoughtful people, manufacturers, etc. Committees were appointed to look into the advisability of having similar work in our schools. They found that the industrial supremacy of European countries was due in no small degree to industrial or manual education. As the result of this investigation manual training high schools were established in different cities of the country. The St. Louis Manual Training School was established June 6, 1879, for instruction in mathematics, drawing, and the English branches of a high-school course and instruction and practice in the use of tools. For the first time in America the age of admission to school shops was reduced to fourteen years of age. The Baltimore Manual Training School was opened in 1883 on the same plane as the regular high school.

In order to meet all the demands of the public, the high school grew to be a cosmopolitan or general high school which offered courses in industrial and commercial work, normal training, general and classical education. It was the intention of the founders of this type of high school not to have it exclusively technical or commercial in character, but with an equal emphasis upon each course of education. It was believed that such a cosmopolitan high school would tend toward democracy in education, whereas specialized high schools would tend toward aristocracy and false notions of the value of other lines of school work. It was said that pupils attending schools exclusively academic in character, not uncommonly looked down upon those who were preparing for manual or commercial pursuits. On the other hand, the high school offering all courses exemplifies the complete life of the community in which it exists and prepares for responsible participation in that life. It gives the pupil an opportunity to observe and compare before making choice of the work to prepare him for his future life. The secondary high school, furnishing an effective system of industrial and cultural courses, is an ideal plan. The experience up to date has shown that to work out this plan has been one of the difficult problems in school administration. The principal of a school usually attempts to impose the standards of the cultural courses as far as possible on the industrial courses. The result is that the efficiency of the industrial courses suffer, as the standards usually exclude or drive out the type of boy who is best fitted for industrial work.[1]

The tendency a few years ago in Massachusetts was to establish an independent industrial school with an independent principal and faculty in an independent building. It is true that not all communities can afford to support an independent industrial school; therefore the industrial department in a high school is the type of industrial education that many small cities and towns must provide.

The clearest thinkers on industrial education have repeatedly stated that an industrial day school is an industrial school established to secure the following ends:

A. Primarily to increase, through proper training of the worker before or after entrance, his efficiency in some trade or occupation.
B. To train for better citizenship.
C. To extend the general intelligence of the pupil.[2]

Very nearly all industrial schools and industrial departments of a high school provide, for boys over fourteen years of age, instruction in wood-working, metal-working, printing, electrical work, etc., regardless of whether the principal industry of the town or city is textiles, tanning, boot and shoe manufacture, paper-making, etc. The reason for this is that all communities have some workers in wood-working, as house carpenters; workers in metals, as machinists; printers; and that all other industries are so highly specialized and organized that every worker performs a single operation of manufacture that can be acquired in a short time. Then again the idea prevails that the factory occupations have not sufficient content of matter to justify a course of study in the school.

There are over two hundred and seventy trades and industries in the State of Massachusetts, a typical industrial State. The average industrial school, when first started, taught practically the same trades. On account of the great expense involved, there may have been some justification on the part of the public school authorities for not supplying industrial education at the entire expense of the taxpayers. But at the present time, with aid from both the National and State authorities, there is no reason why this training should not be provided for all workers.

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[1] See page 218.

[2] See page 211 for course of study.

Experience shows that in an industrial school where the work is not carried on under real trade conditions, it is almost impossible for a pupil to attain a practical skill and efficiency equal to that of a good workman in the trade. Therefore the work in an industrial school should be carried on under actual shop conditions as far as it is possible with the school organization.

Day industrial schools should provide, in addition to the regular courses, which are two, three, and four years in trade training, short unit courses, extending from a few days to a month, which may be given to young people over sixteen years of age, that they may have training to fit them for some highly specialized occupation. These short courses may be called "short unit day courses," and consist of a sufficient number of lessons plus a sufficient amount of practical work to meet the need of a definite occupation. Short unit day courses will appeal to a great many young people who have neither the interest nor the ability to pursue a long course. To the author's mind short unit day courses, for pupils over sixteen, will be the solution of industrial education for the masses.

The economical methods of production, particularly the workman's time as a factor in the cost of production, are difficult to demonstrate to a student, in a school conducted under the best conditions, where his wages do not depend upon his actual productive ability. The skill required for a commercial product can only be understood to best advantage by a student when his product is put to commercial use and when he sees an incentive in the form of wages for his judgment and skill in producing it. Wherever possible the factory or shop should coöperate with the industrial school, so that the shop practice may be given in a factory or shop and the related technical and academic work may be given in the school. This may be done by the manufacturers setting aside a certain portion of a factory for the training of apprentices.

It is clear that the most effective and efficient method of training young people for a trade work is by combining in some way actual shop experience with theoretical knowledge in the school. In this way one obtains the actual skill by participating in a commercial shop on a commercial article under commercial conditions, and the theory or related knowledge may be obtained in a school. Such a scheme of education is called the "coöperative" or "part-time" plan; the pupil spends one week in the industry and the next week at school. This coöperative plan has been adapted to high-school pupils who attend alternate weeks at school. While this plan has some advantages, it has also some disadvantages, as the average young man working at his trade is so constituted that he cannot benefit from such a plan. He is not able to profit by more than eight hours a week schooling. A plan offering from four to eight hours a week schooling to young working people is called "part-time" or "continuation" school.

Evening industrial courses of college grade, secondary grades, are also provided for those already engaged in the trades. In addition trade-preparation courses are offered for young men in unskilled lines who desire to receive sufficient training in skill and trade knowledge to enter a skilled trade.

Outside of the industrial schools mentioned above, there are various systems of training beginners in the different industries. Since the modern organization of industry is on the factory plan, where the manufacturer is concerned in turning out a product in the shortest time at minimum cost, there is a tendency to division of labor. Hand-power is being replaced to a great extent by machinery. The manufacturer is no longer concerned with the training of workmen on a wholesale scale. He finds that on account of the subdivision of labor, the shifting of apprentices from one machine to another in order to train them as all-around men, has a tendency to break up the efficient organization by lessening the production per man. The journeyman working on piece work has not the time to teach the beginner, and in addition feels that the beginner may become a future rival by flooding the labor market and reducing the pay.

The average American boy will not submit to a long apprenticeship of seven years of low wages in order to receive a thorough training. He inherits the spirit of the age, which is to receive the highest possible return for the least expenditure of labor. The result is that the American boy enters other fields, the distributing rather than the productive branches of industry. Then again it is a question whether there is sufficient content in any trade as organized to-day to warrant a boy spending seven or even four years as an apprentice. Nevertheless, every manufacturer realizes that the progressive development of his line of manufacture demands the training of a certain number of skilled mechanics to be future foremen, etc.

Apprentice schools are established by manufacturers to meet this need. They offer definite courses from two to five years in length. The work is both shop practice and theory. The shop practice is given in the shop under a foreman, and the theory or related trade and academic work is given in a classroom not far from the shop, and on the employer's time.[1]

The economical method of production, particularly the workman's time, is a factor in the cost of production. An analysis of industry will show that production depends upon three factors, speed, accuracy, and fitness of the individual worker. Speed and accuracy can be attained by mechanical practice. Fitness is the ability of the operator for that particular occupation, and depends in a large degree on the mental attitude of the operator toward his work. The proper attitude of the worker toward his work determines the proper planning and guidance of the work, so that the greatest return may be obtained for the energy expended by the worker. This means that the greatest industrial efficiency can be obtained only when every worker is trained so as to have an interest in his work, which means appreciation of time, effort, and material, and this can be done only by putting every one through a course of training that will give both practice and theory, as to the best method of performing the work, reason for each step, knowledge of materials used, and care of self while performing the work. To illustrate: A cotton manufacturer desires to employ a number of pickers and carders. A number of men who have recently arrived in this country, with no mill experience, apply for the positions. The usual method of training these men consists of placing them at work immediately, with a few directions in the form of "don'ts" — "Don't place your hand here," etc. The operator soon becomes interested in his work and forgets the directions given to him, unintentionally places his hand on the wrong part of the machine and finds that he has lost a finger or two. He is sent to a hospital and the total cost to all concerned will average quite a sum.

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[1] See page 235 for course of study.

A more efficient plan of training would be to place him with others in a department or part of a mill set aside for a school, under the direction of an instructor, who will explain in simple language the purpose of the operation, how to operate the machine, the names of the different parts and the dangerous parts of the machine. In the course of a week under this form of instruction, the individual will become a more efficient worker, at less expense to the manufacturer and to himself. Well-trained labor will handle efficient tools and machines, so as to reduce the waste and increase the production.

In order to meet this difficulty some manufacturers have instituted a shorter course of apprenticeship which trains for a narrow range of work and fits only for special lines. The worker may be called a helper, assisting the journeyman, performing unskilled work and watching the operations.

QUESTIONS FOR DISCUSSION

1. Is it possible for a young man to-day to become an efficient mechanical engineer by working under an experienced mechanical engineer without attending day or evening courses? If it is possible, why is it not carried out to-day.
2. Why was the development of college grade technical schools slower in England than on the Continent and in the United States?
3. Compare the training of a mechanical engineer in France with that of the training received in the United States.
4. England has very few students attending day technical classes compared to the number attending evening classes. Compare those conditions with those of America, and give the reasons for any differences.
5. What advantage might be gained over the program of studies for mechanical engineering in a college grade industrial school if a certain amount of practical experience were given at the outset and at intervals during the course?
6. What are the advantages and disadvantages in giving technical instruction in advance of practical experience?
7. It has been suggested that students should enter professional schools — that is, a college industrial school — only after some practical experience in the trade or industry. What are the advantages and disadvantages of such a plan?

8. What is the attitude of the general high-school instructor to pupils in the industrial course? Do the industrial pupils measure up to the traditional standards of high-school pupils?
9. Draw a diagram showing the different classes of men engaged in a large industry, and state the institution or type of school that is to give them the necessary training.
10. Compare the type of young man found in a shop with the type of young man found in the drafting-room of an industry.
11. Which type of boy in question 10 will conform to the standards of the regular high-school course?
12. Is there a place for an all-day industrial school for boys between the ages of fourteen and sixteen?
13. What are some of the difficulties to be overcome before a school system can coöperate with manufacturers in regard to training apprentices?
14. What is the difference between a coöperative scheme of education and a continuation school?

LIST OF REFERENCE MATERIAL FOR FUTURE READING

* *Manufacturers' Viewpoint of Industrial Education.* C. R. Dooley. National Education Association. Proceedings, 1912.

(A discussion of industrial education by an educator who has conducted schools for manufacturers.)

* *The Coöperative System of Industrial Training.* A. D. Dean. National Education Association. Proceedings, 1910.

(A discussion of the scheme of education between the shop and school.)

** *Continuation Schools.* Edwin G. Cooley. National Education Association. Proceedings, 1912.

(A discussion of the type of schooling for pupils who leave school at an early age.)

* *Continuation Schools.* Board of Education of Massachusetts. Bulletin, 1913.

(Organization, courses of study and methods of instruction of continuation schools in Massachusetts.)

** *Needs and Possibilities of Part-Time Education.* Board of Education of Massachusetts. Bulletin, 1913.

(Investigation of the need of part-time education in the industrial cities of Massachusetts.)

* *Technical High School.* G. H. North. National Education Association. Proceedings, 1913.

(The aim and value of a technical high school.)

** *Trade Schools in Europe.* F. L. Glynn. United States Bureau of Education. Bulletin issued in 1914.

(A description of different types of technical and industrial schools as seen by Mr. Glynn.)

** *Industrial, Technical, and Art Education.* Ontario Education Department. Bulletin issued in 1912.

(A complete description of different types of industrial schools.)

** *Report of Committee on Place of Industries in Public Education.* C. R. Richards. National Education Association. Proceedings, 1912.

(A general discussion on the aim and value of industrial education followed by a statement of the purpose of different industrial schools.)

** *Intermediate Industrial School.* W. H. Elson. National Society for the Promotion of Industrial Education, 1909.

(A discussion on the need and value of a lower grade industrial school to take care of children who are dissatisfied with the regular school work.)

* *The Fitchburg Plan of Coöperative Industrial Education.* M. R. McCann. United States Bureau of Education. Bulletin No. 50, 1913.

(A description of the first coöperative high-school course.)

CHAPTER V

ORGANIZATION OF INDUSTRIAL SCHOOLS

THE usual plan of organization for the college-grade industrial school, which is usually a private institution, is to have a director or president who is the chief executive officer; a course or curriculum head who has charge of each separate course; a head of each department in the school and a group of academic and technical teachers. Since the aim of this type of school is not to prepare journeymen mechanics, very few ordinary trade (shop) teachers are employed.

Industrial education of secondary or lower grade is usually a part of the regular public school system and is supported by public taxation, with aid from State and National Governments. The chief executive officer in charge of all vocational work should be the superintendent of schools, in a small community, in order to avoid any friction between the different types of education. If the community is a large city, the control should be centered in a director or an assistant superintendent of schools appointed to this work.

The director or assistant superintendent should have a number of assistants. A principal should be appointed for each building set apart for industrial training. Under the principal a number of heads of departments should be selected, to develop the different departments of the school. Three distinct classes of instructors are employed in an industrial school, shop instructors, technical instructors, and academic instructors.

The principal of an industrial school should possess the following qualifications; (*a*) a thorough academic training; (*b*) executive ability; (*c*) experience in public school work;

(*d*) in sympathy with industrial education; (*e*) a distinct industrial point of view; (*f*) sufficient technical and practical knowledge to administer industrial work.

The head of a department in an industrial school should have executive ability, previous experience as an instructor in the department or trade in which he is to act as head, and sufficient technical and pedagogical knowledge to administer the work of the department and to assist teachers in planning the subject-matter to be taught.

A shop instructor should possess the following qualifications: (*a*) knowledge of his trade as full as that of a skilled journeyman; (*b*) knowledge of the technical method in use in the trade, together with a command of its drawing, mathematics, and science; (*c*) general education not less than that represented by an elementary-school graduation or its equivalent; (*d*) technique of teaching and school administration; (*e*) application of the principles of teaching to industrial school problems; (*f*) personal appearance, that will appeal to boys; (*g*) not less than twenty-five nor more than forty-five years when he enters the work.

The technical teacher, sometimes called the instructor of related subjects (applied mathematics, applied science, and drawing), should possess the following qualifications: (*a*) trade equipment, understand the processes of the trade, and the tools that are used; (*b*) some experience as a teacher; (*c*) a general education equal to a high-school education or its equivalent; (*d*) special training in the subject or subjects, two years beyond the highest grade of the industrial school; (*e*) ability to apply these subjects in a practical way to the trade problems; (*f*) personal appearance that will appeal to boys.

The academic teacher, sometimes called teacher of non-industrial subjects, should possess the following qualifications: (*a*) appreciative knowledge of trade and industrial conditions, such as a knowledge of common tools, machines, and processes of the trade; (*b*) experience as a wage-earner in some trade; (*c*) natural mechanical ability; (*d*) general education equal to two years beyond the high school; (*e*) ability to use material drawn from the trades in teaching such subjects as civics, economics, industrial history, and English; (*f*) personality that wins the respect of boys.

In addition to the above, teachers in trade classes should be familiar with the ordinary principles of teaching, how to prepare a lesson, a course of study, and to present a lesson to a group. They should know how to teach economically and effectively, when to use the group method, and when to use the individual method of instruction. The proper relation of the theory with practice, the uses of the blackboard, models, charts, pictures, displays, references to handbooks, journals, and the assignment of home lessons, are some of the essentials of the work that the teacher must handle.

There are certain other personal qualifications that a successful teacher must have. He must be punctual and regular in attendance, have a pleasing personality, the ability to bring the instruction to bear upon the work of the pupils, coöperation with the shops and factories, and the social qualities that will win the respect and confidence of the pupils so that they will attend school regularly.

The average journeyman mechanic when placed in charge of a trade class usually lacks certain qualifications, such as the methods of presentation of the subject, knowledge of the theory, and an all-round knowledge of the trade. Experience has shown that the foreman or overseer who has had a certain amount of executive or supervisory responsibility possesses the above qualifications better than the journeyman. Therefore trade teachers as a rule should be selected from the ranks of foremen rather than journeymen. The shop and technical teachers are the ones that give instruction which directly improves the efficiency of the student in his trade and are often spoken of as industrial or vocational teachers.

The academic teacher is considered, on the other hand, a non-industrial or non-vocational teacher. Experience shows that the academic teacher has a definite place in full-time vocational schools and the general and commercial continuation schools, but fails to fit into the industrial continuation and evening trade classes. This may be due to the fact that pupils that attend the last two types of schools have very practical minds and are unwilling to study or pursue systematically the ordinary academic subjects. The instruction in English and civics must be imparted in an incidental manner from time to time, while the students are studying the technical subjects underlying their trades.

The building used for an industrial school may be either a factory or a schoolhouse renovated. If a new building is to be erected, it is advisable to have the academic department in the front, and in the rear the shops; the front of the building will be of regular school construction, and the rear part of mill construction; that is, brick walls and the timbers exposed.

An industrial school equipment should include equipment equal to that of commercial shops. This may appear to be a difficult task, but nevertheless an effort should be made to have a variety of tools and machines. Many technical schools have made a great mistake in providing a large number of tools and machines of one kind, thus sacrificing the variety of machines.

It is advisable to have an industrial school dominated by the needs of industry. Therefore every school should have advisory committees composed of members representing local trades, industries, and occupations. Experience teaches that these committees should be composed of representative people with little knowledge of the details of educational work. They may be organized by departments into committees of two or three members, a representative of organized labor or employees, employers, and a representative citizen. These committees, as their name suggests, are advisory, and may render very effective service to the school.

The school year of a day vocational school varies from forty weeks of instruction, thirty-five hours per week, five days of seven hours each, to fifty weeks, forty-four hours of instruction per week, of five and one half days of eight hours each. About eighty per cent of the total time should be devoted to industrial instruction, and about fifty per cent of this time should be devoted to productive shop-work, under the direct control of the school. This leaves twenty per cent for general education.

One of the most difficult problems in the administration of a day industrial school is the large mortality factor. The trade course of an existing industrial school is two, three, or four years in length, giving an all-round training in the practice and theory of the trade plus a good general education. A large number of pupils enter the school in the fall, and after they have attended about six months or more, and have learned the names of the tools, and are able to perform one or two of the operations of the trade, they leave to secure a position. It is the opinion of the author that this is due to one or more of the following causes: lack of proper organization of courses, such as short unit courses preparing definitely for some occupation in the semi-skilled trades; lack of proper encouragement from the parents of the boy while he is attending the school; and the narrow view of the boy who cannot place deferred above immediate returns. Instead of the members of the family encouraging him to finish his course at school, they allow him to enter a position with a large initial wage but with very little future.

In order to increase the holding power of the industrial school without modifying the course of study, a number of industrial educators have set up a process of selection at registration, admitting pupils of high-school qualifications who will remain in school and finish the course. A large number of industrial departments of high schools have not been successful in training boys for the productive side of industry because they have set up the requirements, such as scholarship, etc., that exclude a group of young people who would make excellent workers. The graduates of these schools enter the productive side of industry, and remain for a few years, and then become draftsmen, salesmen, etc., in mechanical lines. They fail to remain in that phase of industry for which they have been trained. The training for the distributing side of industry can be given in the regular technical high school or corporation course, supplemented by a proper shop observation and experience, as outlined on page 207, more efficiently than in an industrial course.

The problem of holding pupils in a day industrial school can be solved if we study the type of the great mass of productive workers and adapt a short unit course to meet their needs. We find that usually they fail to meet the requirements of the elementary school above the sixth grade, but nevertheless they possess certain physical and mental qualities, such as muscular strength and mechanical intelligence, that can be trained by imitation to meet the needs of the ordinary occupations of industry and trade. It is from this class that industry must recruit its permanent workers.

The organization of part-time or continuation industrial classes will be very similar to the regular day industrial school, except that the instruction must be more intensely practical and closely allied to the shop. The practical work in the shop must be the basis of the related trade knowledge in the school. This requires the services of a teacher, called a coördinator, to tabulate the shop materials, hand and power tools, shop processes, and other trade activities, that the classroom teacher may know the content to impart.

The organization of an apprentice school consists of a supervisor of apprentices, assistant supervisor, shop foremen, and instructors. The supervisor of apprentices is directly responsible for all general problems affecting the apprentices and supervises the school and shop training. The assistant supervisor is in direct charge of the school and is responsible to the supervisor for its successful operation.

The shop foreman of apprentices is in charge of the instruction in the different phases of shop-work, and the proper application of shop schedules. The shop instructor of apprentices acts as an assistant to the shop foreman and is responsible for the shop instruction of apprentices.

The school instructors conduct the apprentice school instruction as outlined by the supervisor of apprentices. The organization of an apprentice or corporation school is very similar to that of the regular industrial school, except in the names of the officials of the school as described above.

The problems and difficulties are the same as those previously discussed. Of course it must be borne in mind that when a corporation is conducting a school, it is primarily in the interest of the industry, and the corporation feels that it is only bound to give sufficient academic education, or, better still, the related trade knowledge, to make the apprentice proficient in his trade. Little if any attention is given to civics, training of citizenship, and formal English.

Application for apprenticeship is made on a form requiring answers to many questions. This application is looked over, and the apprentice is generally given an oral, written, and physical examination. Wherever possible, preference is given to sons of employees. The apprenticeship is usually three or four years in length.

No. ....

AGREEMENT

OF

APPRENTICESHIP

Between

THE JOHN DOE COMPANY

And

....
(Apprentice)

Made on ....

Fulfilled on ....

THE JOHN DOE COMPANY

NEW YORK CITY, N.Y.

TERMS OF APPRENTICESHIP

1. **Applicants** for apprenticeship must not be less than 16 years of age. They must be physically sound, of good moral character, and have received an education equivalent to that required for graduation from the public grammar school or better.

2. **Application** must be made in person. If accepted the applicant's name will be registered and due notice will be given when he will be required to commence work.

3. **The** first 570 hours shall constitute a term of trial. If the apprentice shall during this period prove satisfactory, and shall before the expiration thereof execute together with some other responsible party an agreement in the form hereto annexed, then his apprenticeship shall date from the beginning of the term of trial and shall continue for the full term, unless sooner terminated, as hereinafter stated.

4. During the trial period the apprentice will be loaned the necessary shop tools and class-room materials. On completion of trial term the set of shop tools shall thereupon become the property of the Apprentice.

5. Apprentices will be required to serve for a term of three or four years, each to consist of 2900 hours, including about 200 hours in the school room.

6. **Apprentices** shall make up lost time at the expiration of each year, at the rate of wages paid during said year; and no year of service shall commence until the apprentice shall have fully made up all the time lost in the preceding year.

7. **The Company** reserves the right whenever the state of business demands it, to shorten the hours of labor or whenever for any reason it shall stop the working, or suspend wholly or in part, and the making up of lost time in this way shall be at the discretion of the Company.

8. **The Apprentices** will be required to perform their duties with punctuality, fidelity and diligence; and to conform to the rules and regulations which are, or may be, adopted from time to time for the good government of the shop, and the Company reserves the right to itself, at its sole discretion to terminate an agreement, and discharge the apprentice from further service for any non-conformity with rules and regulations, want of diligence to his business, or improper conduct in or out of the shop.

9. In case of discharge, or in the event that said apprentice shall abandon his apprenticeship before the expiration thereof, without the consent of said Company, the apprentice shall forfeit all wages then earned and unpaid.

APPRENTICE AGREEMENT

THIS AGREEMENT is made this .... day of .... 19.... between the JOHN DOE COMPANY, INCORPORATED, doing business in NEW YORK, N.Y., hereinafter known as "Company" and

.... of ....

hereinafter known as "Apprentice," and ....

of .... hereinafter known as "Guardian," whose relationship to the Apprentice is that of ....

For the purpose of acquiring the Art or Trade of MACHINIST AND TOOL-MAKER said .... hereby becomes an Apprentice to the Company and the Company hereby accepts him subject to the terms herein stated.

The Apprentice and his Guardian hereby promise that the Apprentice shall conform to and abide by all the provisions of this agreement, and shall faithfully serve the Company during the full period of time named in this agreement.

The Apprentice agrees during the period of his apprenticeship to do all in his power to learn said art or trade and earnestly and loyally to promote the interests of the Company. He also agrees to pursue classroom studies when they are required and arranged for by the Company and in that case to do a reasonable amount of home-study in preparation thereof.

It is agreed by the Apprentice and his Guardian that the Company shall have the right at any time to discharge the Apprentice for lack of diligence, indifference to business, inability for the work, disobedience of rules and regulations of the Company, or improper conduct in or out of working hours and to suspend him if the state of business should demand it.

In consideration of the agreements on the part of the company herein contained the said Apprentice agrees that he will pay the Company the sum of $25.00—said sum to be paid by said Apprentice at the expiration of the term of trial referred to in said "Terms of Apprenticeship," this to be returned to the Apprentice upon graduation.

The Company agrees to train and instruct the Apprentice in said art or trade and to pay him compensation as specified in this agreement for his services as Apprentice. The Company also agrees that if the Apprentice shall remain in its service for the full period of his apprenticeship, including whatever period is required to make up lost time, and shall in every way comply with the terms of this agreement, to present to the Apprentice at the termination of his Apprenticeship a bonus of ONE HUNDRED DOLLARS ($100.00) and a Certificate of Apprenticeship signed by an officer of this Company.

This agreement shall cover a period of FOUR years including a trial period of 576 working hours. Each year shall consist of 2400 working hours.

The apprentice shall receive from the Company during the period of apprenticeship the following compensation, to wit.—

15 cents per hour for the first year.
18 " " " " " second year.
22 " " " " " third year.
26 " " " " " fourth year.

JOHN DOE COMPANY, INC. ....
APPRENTICE

Per ....
GUARDIAN

Signature must be written in full and with ink.

During the course the pupil receives a training in the practice and the theory of the trade. The practice is given in the shop and the theory is given in the school. The hours are the same as for the journeyman, except for four hours a week, when the apprentice attends school on company time at the regular rate of pay. At the end or expiration of apprenticeship, those who have satisfactorily completed the course receive a certificate, signed by the proper officials of the company. They are retained in the employ of the company at the specified rate, or at a higher rate, if the ability and service justify same.

QUESTIONS FOR DISCUSSION

1. Explain why few shop teachers are employed in an industrial school of college grade.
2. Are instructors in schools of technology inclined to explain principles in terms of "shop" or technical language?
3. How would you proceed to select a teacher for applied science in a day industrial school?
4. Why is it necessary for the principal and instructors in a secondary school to have a sympathetic understanding of boys?
5. Is it possible to have the same rigid standard in a coöperative industrial class, and hold the pupils as in the regular high school?
6. Why is it desirable to defer industrial education until the end of the period of compulsory general education, fourteen years of age?
7. Some instructors in trade and industrial schools claim you cannot teach a trade to a boy until he reaches the age of sixteen. Why?
8. What objection may be made against teaching a child of ten to be a textile worker "piecer"?
9. Does a course in civics assist industrial training? If so, to what extent?
10. Should industrial and liberal education be combined? State the advantages and disadvantages of such a plan.
11. How should the time be divided between industrial and liberal education?
12. Should studies in an industrial course be alternated by hours, as in the regular high school, or shall the day be so divided that one half may be given to shop practice?

LIST OF REFERENCE MATERIAL FOR FUTURE READING

*_Statement of Policies of Federal Board for Vocational Education._ Bulletin no. 1.
(A number of fundamental principles of vocational education.)

*_Emergency Training in Shipbuilding._ Evening and Part-Time Classes for Shipyard Workers. Bulletin no. 8
(Unit courses in shipbuilding showing how short, intensive courses may be used in training workmen.)

*_Trade and Industrial Education._ Bulletin no. 17.
(A very concise statement of the organization and administration of industrial schools.)

*_Part-Time Trade and Industrial Schools._ Bulletin no. 19.
(A complete description of the organization and courses in part-time industrial schools.)

*_Buildings and Equipment for Schools and Classes in Trade and Industrial Subjects._ Bulletin no. 20
(A description with illustrations of the growth of different industrial schools. Kinds of buildings and equipment.)

All the above may be obtained from the Federal Board for Vocational Education, Washington D.C.

*_Organization of the Pennsylvania Railroad Apprentice System._ Circular published by the Pennsylvania Railroad
(A very elaborate organization of apprentice schools.)

**_Problems of Industrial Education under Public Administration._ Frank V. Thompson. National Society for the Promotion of Industrial Education. Proceedings, 1916
(Discussion of some administrative problems that have arisen in the administration of schools in Boston.)

**_Requisites of the Efficient Teacher in Industrial Schools._ G. M. Gering. National Educational Association. Proceedings, 1911
(A discussion of the qualifications of an efficient teacher in an industrial school.)

DIRECTOR OF INDUSTRIES
Bengal

CHAPTER VI

ORGANIZATION OF EVENING INDUSTRIAL COURSES

THE history of trade and technical instruction shows that originally organized technical instruction consisted of engineering, mathematics, drawing, science (theoretical and laboratory practice), and was provided for young apprentices during the evening. This was due to the tradition that all students were expected to be working under some form of apprenticeship in the trades and industries and received the practical training in the shops during the day. The first form of technical and trade instruction was naturally planned to supplement practical experience by giving the related trade knowledge in the evening. England to-day practically provides very nearly all the technical instruction in the evening classes on this basis.

While it is necessary to provide well-trained workers, it is also necessary to provide employers, managers, and foremen having the proper appreciation of the value of the technical training of workers. The higher degree of training necessary for the worker, the greater the need of raising the standards of the managers, foremen, etc. Therefore it is necessary to have different grades of evening technical or industrial schools or, as they are sometimes called, extension courses, as well as day schools.

Evening industrial extension courses or evening industrial courses may be of the same grades as the day industrial school, college grade and secondary. The college grade evening industrial school aims to bring the systematic study of applied science within the reach of young men with a high-school education or its equivalent who are following industrial pursuits, and who desire to fit themselves for higher ositions, but are unable to attend courses during the day. The Lowell School of Foremanship represents an evening technical school of college grade.[1]

Evening school instruction has been, and probably will be or a long time to come, the only feasible form of organized ublic instruction for working boys and men. In order to how the relation between general evening schools or evening chools of liberal instruction and vocational evening instruction (including industrial classes, given under the public chool system), it may be well to outline a plan showing the xact relation.

Evening instruction under these two divisions may be utlined as follows:

A. General or liberal education.
    I. Regular elementary grade schools for those wishing to complete the elementary school course.
    II. General course (ungraded) for
        a. Illiterates.
        b. Foreigners.
    III. Regular high-school courses for those wishing to complete the high-school work along the following lines:
        a. College preparatory course.
        b. Commercial course.
        c. Classical course.
        d. Technical course:
            1. Courses for boys who desire to be "handy."
            2. General technical course (technical training to enter a skilled line of work).
    IV. Recreational courses.
B. Vocational courses.
    I. Trade preparatory courses:
        Desire of sufficient training to enter from a blind-alley to a skilled employment.
    II. Trade extension courses.

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[1] See page 204 for course of study.

In addition to the college grade, secondary and intermediate industrial classes should be established. The secondary class is for those who desire to learn more about the practice and theory of the trade. The intermediate class is for beginners who are in unskilled lines and who desire to learn sufficient practice about a skilled trade to obtain a position. The secondary evening industrial classes are sometimes called trade classes or trade extension classes, and represent one of the most important divisions of industrial education.

The organization of evening industrial classes should be under a principal or director, with a corps of shop and technical instructors. The qualifications of the principal and instructors should be at least those required of the principal and instructors in day industrial schools.

Since evening school work is exacting, only those teachers should be selected who are physically strong and robust. As all forms of evening instruction are more or less of a social problem, it is very important that teachers should be imbued with a real desire to assist their pupils, as well as to know the subject of instruction. They should know all the members of the class, be able to assist them with advice and to arouse the tired pupils by enthusiasm. All this requires a great deal of energy (physical) on the part of the teacher.

Evening trade instructors should possess a trade training plus a combination of personal qualifications to deal wisely, cheerfully, and sympathetically with tired apprentices. It is customary to select evening instructors from the day school force. While this is often advisable in order to prevent teachers from having conflicts over equipment, it does not always give the best results. The most efficient day school teachers often fail to give the best results in evening classes. This is due to several reasons: evening trade pupils are usually tired apprentices who attend school with very definite ideas as to what they require. They desire instruction which will lead to definite needs, usually some deficiency in their daily occupation or a desire to secure a promotion. Therefore evening trade teachers require, first, a large social democratic spirit; second, the ability to interpret the needs and desires of the pupils who attend the evening schools.

Trade extension courses have usually been planned as two-, three-, or four-year courses. Students have been placed in either the first, second, third, or fourth year according to their ability. The records of evening trade classes under the above organization have not been satisfactory. The mortality of students has been very great. Investigations have disclosed a number of weaknesses in the evening school organization, such as incompetent teachers, poor organization, classes not adapted to needs of pupils, etc.

Apprentices and tradesmen demand that the instruction shall lead directly to the specific things they want to know. If they are obliged to spend a month or more on preliminary work, the value of which they do not immediately discover, they will soon become discouraged and leave. Then again, mechanics and other tradesmen who may, perhaps, have some reputation in their trades, and who wish to perfect themselves in certain technical lines, do not wish to be grouped with younger persons, feeling that such persons, having come recently from the public schools, are able to answer questions, use better English, and appear to better advantage than they. In other words, adults are often sensitive about the comparisons which the younger members are apt to make at their expense. Therefore, all trade students should be classified into vocational classes, according to their trades. This idea carries out the plan of the old trade guild of a few centuries ago. Each guild was formed for the purpose of social intercourse and mental stimulus. Each trade had its own guild, and the daily trade experiences of each member became the property of all members. Discussions relating to the practices of their chosen trade occupied their attention. So to-day workmen have common trade interests, and should be grouped according to their occupations so that they may have an opportunity to talk over those interests.

Since workers usually attend a technical class in order to satisfy a definite need, the instruction should be divided into a series of units, each unit representing a definite trade need. To illustrate: a machine-shop course may be divided into the following unit courses:

1. Lathe work, and the use of measuring instruments.
2. Screw-cutting.
3. Planer and shaper operating.
4. Milling-machine operating.
5. Tool and die work.
6. Jigs, fixtures, and machine construction.
7. Machine-shop mathematics.
8. Blue-print reading and machine drawing for machinists.
9. Tool design.
10. Tool forging

Each unit course may consist of sixteen lessons of two hours each distributed over eight weeks. An applicant may enter any one of the above unit courses and meet his immediate need. He may desire to continue in other unit courses after he has seen the value of his first course.

Of course it is possible to have full courses composed of multiple units. There are some students who desire to pursue a vocational course covering from two to four years. Therefore unit courses should be arranged in sequence so that it is possible for a student to obtain a complete knowledge of the trade by attending a number of years.

Evening trade classes present so many new situations and new problems to be solved that it is necessary and very essential that the faculty should have frequent discussions; daily lesson outlines on mimeographed sheets, the problems prepared by the teachers and used as a guide and a summary by the pupils. Pupils in evening trade extension classes should not be graded or grouped as are the regular pupils in the evening schools. An effort should be made to determine whether a pupil can profit by the course. Regularity of attendance should be insisted upon, and absences excused only on account of sickness or work. If a pupil fails to attend regularly seventy-five per cent of the evenings, he should be dropped, and should not be reinstated until the opening of the next unit course. Trade classes should not be in session over two evenings a week, and those evenings should not be successive. An individual card should be kept for every member of the class. One side of the card should contain the history of the pupil, and on the reverse side the attendance, the amount of work done, and the time devoted to each project. At the end of the year these records should be transferred to a larger card, called a life card, which becomes a permanent record.

In order to make short unit courses successful it is absolutely necessary to have the courses properly advertised. This brings up the very important question of the advertisement of trade extension courses. These courses should be widely advertised through circulars distributed to mechanics and tradesmen, through the daily newspaper, and by means of posters placed in conspicuous positions in the shops and factories. Large, attractive posters should be placed on the walls near the exits and entrances of shops and factories, railroad stations, ferry slips, clubs, unions, and schools. Notices should appear frequently in technical journals, in special bulletins, and in papers issued by large corporations.

Slides showing the value of trade extension courses should appear in the moving-picture houses. Once a year the school should have a public day; that is, the school should be open to the public with the equipment and plant running. The principal and instructors should be present to explain to the visitors the different departments in the school. An evening at the close of the term should be devoted to an exhibition of the work accomplished and a special invitation should be extended to journeymen and apprentices. In addition — the principal should address various civic bodies and labor unions on the value and need of trade extension classes, and make personal visits, regularly, to the local shops and industries, and meet the foremen and overseers and ask them to encourage the workers to attend the evening trade classes. It is very important that the wording of all circulars, posters, etc., should be expressed in a concise, attractive form. To illustrate; instead of shop mathematics, use arithmetic for machinists, arithmetic for carpenters, etc.

A deposit should be required for admittance to trade extension courses. It is a sign of good faith and is a guarantee against irregular attendance, breakage, stealing, and misuse of materials. This deposit should be returned at the end of the term if the pupil has attended regularly, has properly used materials, and returned books and instruments. A fee of one dollar for each course would be sufficient.

In order to maintain a uniform attendance it is a good plan to have various employers visit the school and make their appearance on the platform before the assembled classes. An effort should be made to have employers address the students and show the value of this type of education, enumerating if possible personal references. A list of employees who have attended the school, with a record of their progress and attendance, should be sent to employers, so that they can reward in a substantial way the attendance at the trade school, by promotion, some form of preference, or by increase in wages.

When a student is absent a card should be sent to him, and if he does not respond, a letter should be sent to his employer or a visit made to the shop.

Since there are many occupations that are highly specialized and which do not possess sufficient content to give a course of study over several years, it is necessary to provide, in addition to the evening trade courses, a form of recreation that will appeal to the working pupils. In order to carry on this work successfully, trained teachers should be provided who are able to mingle easily with working people, and, above all, they should have the power of leadership for all forms of recreational work, from free play and folk-dancing to clubs and lectures. This work requires a strong leader, a person who leads but keeps himself as one of the crowd, thus putting the leadership as little in evidence as possible. These activities are of tremendous value in inculcating the art of coöperation, civic and social responsibility, and social good feeling, and should have their share of attention in evening schools especially in industrial districts. Pupils should be taught as far as possible to use their own homes for amusements. The schools should have rooms, halls, gymnasiums, etc., with furniture and supplies for games, reading-rooms, recreation-rooms, and moving-pictures. Classes should be arranged so as to accommodate a group or groups that have corresponding interests. Athletic games should group together those best suited to play together. Table games and story-telling and folk-dancing all need grading, in a sense, so as to keep a relatively keen interest.[1]

Intermediate evening trade classes are sometimes called evening trade preparatory classes, and are for those who desire to enter a skilled trade. Since the students in the trade preparatory classes have not had any trade experience, most of the instruction should be in the shop.

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[1] See page 302 for course of study.

QUESTIONS FOR DISCUSSION

1. A number of prominent English technical school educators claim that it is difficult to obtain a large enrollment of day students in technical schools. Give some of the reasons why this condition exists.
2. What are the reasons for the increased demand for evening schools during the last few years?
3. Is an evening course in machine-shop theory more effective than a correspondence course in the same subject? Why?
4. Explain the advantages and disadvantages of short unit courses covering a number of evenings, and full courses covering two years or more.
5. Suggest evening courses for cotton-mill workers
6. Suggest evening courses for electrical workers
7. Explain why evening trade instruction for young people on the Continent of Europe is not popular Compare the length of the working day on the Continent of Europe with that of the United States.
8. How can evening school teachers of trade subjects be kept in intimate contact with the practical requirements of the trades they are teaching?
9. What is the most effective means of securing (*a*) evening shop teachers. (*b*) evening technical teachers?
10. What is the purpose of an advisory board for an evening industrial school? How may they be selected?
11. What is the most effective method of giving evening instructors trade experience?
12. What are the agencies available for industrial education in the average community?
13. What are the qualifications required for a director of (*a*) an evening preparatory trade school; (*b*) a continuation school; (*c*) an evening trade school?
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QUESTIONS FOR DISCUSSION

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CHAPTER VII

AN INDUSTRIAL SURVEY

It is necessary to experiment in industrial education, as in other lines, to make progress. In order to work intelligently, it is necessary to profit by the results of other communities, and to obtain data upon which to experiment. Therefore, before establishing any system of industrial education, it is desirable to make a number of investigations or surveys for the purpose of determining just what kinds of industrial training are required.

The main questions to be answered by a survey are:

1. To what extent is there a need for industrial education in the community?
2. To what extent are the public schools, private agencies, and apprenticeship systems meeting the need?
3. What kinds of industrial training are needed?
4. How can coöperation be arranged between the schools and the trades and industries?

A thorough study should be made of all the industries in the community to determine the following questions:

1. Whether there is a content of technical knowledge or skill in any job that cannot be acquired through routine work for which special instruction is needed.
2. If so, what is it?
3. Whether it can best be imparted by provisions inside the industry.
4. If not, whether it is worth while to provide such instruction through outside agencies.
5. If this is true, whether such instruction shall take the form of—
    - *a.* All day industrial schools.
    - *b.* Trade schools.
    - *c.* Part-time industrial classes.
    - *d.* Evening classes.

6. Whether there are any jobs for which it is not desirable either to direct the youth or to train him at public expense.
7. What number of new workers could be prepared for any job, if it has a teachable content, without overstocking the market?
8. What kind of equipment as to age and physical and mental assets should the worker have for the job?
9. To what extent does the industry select its workers for any job so as to secure those best adapted to it?

The answers to the above questions will show the types and extent of the schools needed, the courses of study to be followed, and the equipment and try-out necessary to carry through the aims and purposes.

It is coming to be recognized that in some industries the training of the workers should be as much a matter of trade agreements as hours of labor, scale of wages, grievance boards, and other matters which ultimately and vitally concern both the employer and employee. These are dealt with by means of a joint agreement known as the "Protocol." Trade agreements may be worked out covering the following:

1. The conditions under which new workers are to be trained and received into the trade or occupation.
2. The credit toward the period of apprenticeship to be given any course of training in the school either before or after employment.
3. The training in schools as well as shop to be required of the apprentices after employment.
4. The preference given to local and trained workers in hiring and promoting in the trade and occupations.
5. Possibilities and arrangements for instruction during the dull season periods of trades.

As a matter of efficiency every school system should take account of the social, economic, industrial, and educational conditions in the community. Data should be at hand and kept up to date. The superintendent or assistant superintendent should be able to interpret the data collected and use them to advantage in developing the school system. The following suggestive outline may be used by attendance officers, investigators, and social workers in obtaining the information:

1. Facts about the people. (While this may be somewhat too inclusive as a major division, it is used here in the restricted sense of a single locality.)
   - *a.* Population extent. The whole program will depend much upon the size of the community.
   - *b.* Migration. That is to say, whether or not the population of the city is stable or movable.
   - *c.* Conditions as to type.
     1. White or colored.
     2. Native or foreign-born.
   - *d.* Illiteracy.
2. Economic factors.
   - *a.* Tax-rate, local and State; the whole tax burden.
   - *b.* The indebtedness of the town or city.
   - *c.* Conditions of waste in the expenditure of all public moneys.
   - *d.* Possibilities for effecting economies by a reorganization of the present system of education.
   - *e.* The amount of school funds, from whatever source, available for local use.
3. Industrial factors.
   - *a.* Apprenticeship.
     - (1) How extended.
     - (2) Lack produced what result.
     - (3) How to supply lack.
     - (4) Not needed because of type of labor employed, mature workers only, etc.
   - *b.* Whether there is a content of technical knowledge or skill in any job that cannot be acquired through routine work, and for which special instruction is needed.
     - (1) If so, what is it?
     - (2) Whether it can be best imparted by provision inside the industry.
     - (3) If not, whether it is worth while to provide for such instruction through outside agencies.

- (4) If this is true, whether such instruction shall take the form of
  - (a) All day industrial schools.
  - (b) Trade schools.
  - (c) Part-time industrial classes.
  - (d) Evening classes.
- (5) Whether there are any jobs for which it is not desirable either to direct the youth or to train him at public expense.
- (6) What number of new workers could be prepared for any job, if it has a teachable content, without overstocking the market.
- (7) What kind of equipment as to age and physical and mental assets the workers should have for the job.
- (8) To what extent does the industry select its workers for any job so as to secure those best adapted to it.
- (9) Whether their market is overcrowded.

4. School factors.
   - a. The number of children leaving school each year.
   - b. The nationality, age, and schooling condition of those withdrawing.
   - c. The economic condition of those withdrawing.
   - d. The wages, number of jobs, kinds of work, and advancement of those withdrawing.
   - e. Causes of retardation.
   - f. Causes of withdrawal.
   - g. Education after leaving school.
   - h. Means of getting a job.
   - i. Comparative amount of idleness of non-graduate, graduate, and high-school group.
   - j. The aim, character, and extent of prevocational training in the elementary schools.
   - k. The aim, character, and extent of manual training in elementary and high schools.
   - l. The aim, character, and extent of the evening schools.

Since the public school system is expected to train pupils of high-school age for the vocations in the trades and industries, it follows as a corollary that this industrial instruction must be supplemented by industrial guidance. Otherwise the public schools may be flooding certain trades with young men, to an extent that there may be more applicants than positions to be filled. Such a condition would be harmful to society and to the student. Therefore the most efficient system of industrial education must include, as a preliminary course, industrial guidance, information and direction to young people, in order that they may be distributed vocationally so as not to have an excess of human talent in any one field.

In the early history of the race, it was the custom to place the growing boy at work with his father, so that he might be taught from the experiences of his father. During the Middle Ages the training in the apprenticeship was a direct preliminary to his trade. To-day parents do not care to have the children follow the father's occupation, on account of the feeling that the children should do better than the father. This is a serious mistake because children sometimes do not do as well as their fathers, and if they followed their fathers, they would be imbued with the industrial atmosphere and features of the trade.

Years ago, when each community was small, the industries and trades were open books to each boy. It was not unusual, as we see from the life of Benjamin Franklin, for a father to take his son at the age of twelve to the different shops, to see the men at work and to talk to the master-workmen. Comenius speaks in a way of industrial guidance, when he says, in speaking of the true significance of manual occupations as a factor in education, that children should learn the most important principles of what goes on in the world around them, so that any special inclination toward things of this kind may assert itself with greater ease later on.

The responsibility of preparing a young person for a vocation for which he is fitted physically and temperamentally will be one of the most serious duties imposed upon the public school system, because eventually it means that the problem of supply and demand of labor and the problem of distribution of human talent will be placed on, or correlated with, the public school system of this country. This is one of the reasons why this vital problem should be solved in a careful, scientific way, with due regard to each person's aptitudes, abilities, resources, and limitations, and at the same time taking into account the relation of these elements to the opportunities and conditions of success in the different fields of labor. Children should be employed in positions for which their health, capacity, and intellect best adapt them. If this is done, it means well-rounded and efficient manhood and womanhood. On the other hand, an occupation out of harmony with a young person's aptitudes and capacities means inefficiency and a loss to both the employer and employee. A large number of adults who prove to be failures in life can trace the cause to the lack of proper guidance in both school and juvenile employment.

The vocational direction or guidance department of a public school system should be a part of the organization of the continuation school, and should be in charge of a director called a "vocational counselor." This director should have full power over the granting of working certificates and providing employment for young people who desire to go to work.

A vocational counselor should be a person with a sympathetic interest in young people. In addition, he should have information in regard to the opportunities for work for young people. In order to obtain this information, the counselor should have an appropriate personality to approach employers, and the ability to do research work and to organize this information in proper form for use. This may be carried out by dividing vocations into five large classes, the professional, the commercial, the agricultural, the industrial, and the household. Under each class we may have divisions and subdivisions of occupations. A record of qualifications and of the supply and demand of different positions should be on file. A chart may be made illustrating the educational opportunities in the community. The survey will show the positions open to young people by using data given on page 62 in the form of a chart, which has been used successfully by the National Society for the Promotion of Industrial Education.

In order that the vocational counselor may properly look after the welfare of the individual child, it is necessary to know definitely the time the child should begin work and the kind of work he is able to do. Physicians tell us that the mental and physical condition should not be overshadowed by being brought into use before the development adapted to such use is established; and on the other hand, that functions, both mental and physical, are weakened by not being brought into use when they are ready to be used.

The mental development of the child should be carefully determined to see whether the child should be allowed to work. Before this is done, it is necessary to know the nature of the work the boy or girl is to perform. After it is determined by tests that he or she has the mental equipment and the degree of knowledge necessary to do a certain form of work, the next question to be solved is whether his physical condition is such that this particular kind of work will not harm him. Since labor differs in character, occupations should be classified, and the boy or girl should be allowed to perform only the character of work that is best adapted to his or her physical condition.

Since the knowledge and training imparted to a child are to prepare him for life, the school should follow up the boys and girls who leave, and see how successfully these children have been prepared. The school is to judge by the success or failure of the children who are out in the school of life. A continuation school teacher should be assigned to look after a definite group in addition to the regular school work.

QUESTIONS FOR DISCUSSION

1. What are the objections usually raised in a community against an industrial survey? Are the objections well founded?
2. Explain some of the reasons why "Protocols" are not more commonly used in industrial education.
3. Are social workers alone competent to carry on an industrial school survey?
4. Are so-called general educators alone competent to carry on an industrial school survey?
5. What are the preliminary steps usually taken before an industrial school survey is made in a community?
6. How was vocational guidance provided a generation or two ago?
7. What objections are made to vocational guidance?
8. Give some reasons why the public school system should support a well-organized vocational bureau. What are some of the objections usually made against such a bureau?
9. Explain how the public school system may assist in solving the problem of the unemployed.
10. Outline the organization of a vocational bureau for an industrial city of 500,000 inhabitants.
11. Give some of the reasons why every child should be under the guidance of the public school system until he or she reaches the age of eighteen. What are some of the objections to such a plan?

LIST OF REFERENCE MATERIAL FOR FUTURE READING

* Report of the Minneapolis Survey. National Society for the Promotion of Industrial Education. Bulletin no. 21.

(A very comprehensive study of the industrial educational needs of Minneapolis. Forms and questionnaire are very valuable.)

** Report of the Richmond Survey. National Society for the Promotion of Industrial Education. Bulletin no. 20.

(A study of the different trades and industries of Richmond, Virginia, to determine educational needs.)

** The Vocational Survey of Cincinnati. Chamber of Commerce, Cincinnati, Ohio.

(A chamber of commerce investigation of the educational needs.)

"Vocational Information for Pupils in a Small City," M. A. Wheatley. *School Review*, March, 1915.

(A study of vocational guidance in a small city.)

* "Vocational Guidance in Boston." F. V. Thompson. *School Review*, February, 1915.

(A description of the organization of the vocational guidance department of the school system of Boston.)

** *Readings in Vocational Guidance.* Meyer Bloomfield.

(A collection of the best articles on vocational guidance.)

Vocational Guidance and the Public Schools. Associated Academic Principals and Councils of Elementary School Principals and Teachers. Proceedings, Syracuse, New York, 1919

(A splendid discussion on how the public school may assist vocational guidance.)

CHAPTER VIII

PRINCIPLES OF PSYCHOLOGY UNDERLYING LEARNING

In order that one may have a clear understanding of the methods of teaching industrial education, it is necessary to have at least a working hypothesis of the action of the mind in acquiring knowledge and skill. The immediate organ of the mind is the nervous system which consists of the brain, spinal column, the cerebro-spinal nerves, and the sympathetic system of nerves which maintains the automatic action of the organs of respiration, circulation, and digestion. All of these parts form a complete system; the nerves and the spinal column are merely extensions of the brain tissue. The nerves, which extend to every part of the body, appear like white, silvery threads, branching and ramifying from the roots which are sent from the spinal column through lateral holes in the spine, and to the brain from the organs of sense through the holes in the skull. Each nerve has two parts, the *motor* and *sensory* cords; these two cords run side by side, and form one thread bound by many twisted fibers that conduct the nervous energy and nutrition to and from the nerve centers. The two cords are distinct in each nerve, and serve a distinct purpose. The *sensory* cord carries sensations or *sensory* impressions that it receives to the brain or spinal column, and the *motor* cord carries the reactions from the brain — that is, the intellect — to every part of the body. Each cord acts independently except as they meet in the brain. The brain is divided into two hemispheres or lobes, associated with each other by fibers which unite them. The center of the brain contains the section that regulates the activities of the special senses, *smell*, *sight*, *hearing*, *tasting*, and *touch*.

Organs of sense do not at once act in their full measure in the child. They do not possess at the birth of the child their full power or precision, as in the case of animals, such as the power of smell of a dog. The first applications of sense-perception need to be corrected by experience. Each sense assists the other, and gives approximate perfection to sense-perception. Knowledge is best obtained by the combined exercise of all the organs of sense. Exercise strengthens the organs and makes them accurate.

The eye, the organ of seeing, is one of the most important organs. It at first perceives only surface and color, but it is trained by experience with the aid of the other senses to perceive texture, figure, size, number, and distance. By training the eyes, the dyer is able to detect differences in shades of color, and other skilled workmen (tradesmen) are able by inspection to detect imperfections and strong points in material.

The ear reveals sound. It is aroused by vibratory movements through the air to the ear. The ear, which at first is quite inactive, and very gradually discriminates sound, may be trained to perceive shades of tone. Experienced mechanics are able to detect weaknesses in engines and machine parts by the sound produced from the blow of the hammer which the ordinary person would be unable to discover.

The tongue reveals taste. The organ of taste is the surface of the tongue and palate on which are distributed nerves. In order to excite the sensation of taste, it is necessary to have the substance in a state of solution. Continuous stimulation rapidly deadens its sensibility. It is hard to arouse this sense. It may be cultivated to a great extent by practice. Merchants and others are able to make the selection of certain commodities and to detect impurities by the sense of taste.

The sense of touch; the nerves of touch extend to every part of the body and receive impressions at their extremities; in the fingers they terminate in a fold which is especially sensitive to vibration. When we touch an object a flow of nerve energy or sensory impression is sent through the sensory fiber to the cerebrum forming a sense-perception.

The nose reveals smell. The organ of smell is the membrane lining the inner surface of the nose. Odorous particles are emitted from the substance, pass over the membrane, and stimulate the nerve fibers. It resembles taste to a certain degree, in that continuous action will render the organ useless. Certain tradesmen possess this sense to a marked degree.

Of course we know that we can enlarge the scope of knowledge to be obtained by the eye and ear by artificial aids; the microscope and telescope assist the sight, and many other scientific inventions assist the hearing. We can improve and intensify the powers of sense by special practice; the surgeon trains the hearing, touch, and sight; the carpenter trains his eye and hand to work together in sawing wood. The expert finisher on cloth trains his touch so as to detect slight differences in the texture of fabrics that are not visible.

The brain and nerves like all parts of the body develop very slowly. The child is born with certain tendencies that come by heredity. These tendencies are called "instincts." The education of the child is a matter of inheritance and such habits and knowledge as are acquired by environment. The child's first education is received through the senses; that is, the child receives an impression first upon the organ of sense, which is transmitted by the sensory cord to the brain, where it makes an impression. As a result of a number of these impressions called "sense-perception," the senses are exercised, and a certain movement of the mind takes place called a "reaction," which is transmitted from the brain to the body by the motor cord. Certain actions that are repeated many times create such an impression on the part of the brain, the spinal column, that it puts forth motor actions that become automatic; that is, carried on without connection with the brain itself. This power is called "habit," or the reflex action of the spinal column, and is shown in walking, etc., which at first requires intellectual direction, but through repetition is performed unconsciously, through habit. To illustrate: the first time a boy saws a board he is obliged to make special nervous effort to do the work, and finds great difficulty in sawing according to the pencil mark. There is a tendency for him to saw at a slight angle. The second time it may be somewhat easier. After a number of trials he is able to saw straight to the line. After a while he is able to saw with very little mental effort. This is due to the fact that he has acquired the habit or skill of sawing a board to the line. Each time he performed this operation it required a certain coördination of the eye and the hand, and finally the response became automatic in its action; a tract (mental) has been produced which can be aroused very easily. In the case of academic work, pupils must perform exercises and problems to a great extent in order to obtain the power or habit to remember how to solve future problems quickly and easily. An educational device called "drill" is used to produce this habit.

Sometimes it is desirable to break off certain habits. In order to do this, it is absolutely necessary that the pupil should have a real desire to break off the old habits and enter into the drill or practice for the new habits with considerable initiative, and never allow an exception to occur until the new habits are securely formed. A teacher should secure the interest of the apprentice or students from the beginning to the end of the lesson or drill, so as to utilize the energy of the interest or previous habit to the best advantage. This requires close supervision in the early stages of the habit to form accuracy. Speed will be developed later.

Every normal person is born with a healthy mind including the senses. In addition there are certain inherited tendencies or impulses called "instincts," like curiosity, emulation, love of outdoor sport, etc. Some of these instincts are born with us, others keep popping up from birth to adult life. A boy of fourteen years may be prompted by the instinct of curiosity to examine an electric bell, to see how it works.

Instincts are very important in educating the child, for we build on the good and try to stifle the bad ones. It is of importance to consider the natural order and sequence of developing instincts, the normal age of the child for the first appearance of the different instincts, and the condition of their future growth. The development of many instincts is largely dependent upon that of others. Instincts may or may not appear at the same period in the abnormal child as in the natural child.

Life may be divided into four parts; infancy, from birth to six years; childhood, from six to twelve years; adolescence, from twelve to manhood; and adult. The infancy period is the time of life of greatest activity, when the child appears to consist mostly of bundles of instincts, such as locomotion, curiosity, grasping, and imitation. It is through these instincts that the child is educated. At the age of five or six a child is able to walk with ease and grace, but his precision of movements of hands and fingers is about three fifths that of a boy of sixteen years of age.

The second period, childhood, is marked by less violent or more directed self-activity. The greatest instinct is the play instinct. It is both expression and means of education. Education during this period may be assisted through play. It is during this period that memory, the mental power of retaining sense-perceptions, is developed. It is the developing of this power that gives us knowledge, for we must retain knowledge in order to possess it. The growth during the period of life from ten to twelve is slow, and a surplus of energy is available. It is the time when the play instinct is strongest, and a period for the development of facility and skill, when drill exercises for the formation of habits may be given with least harm.

Adolescence is the period of change. It is a time when a great many children put aside childish things and begin to think of the serious side of life, self-support. The period may be divided into three stages, embracing respectively the ages from twelve to sixteen, from sixteen to eighteen, and from eighteen to twenty-four. Some authorities have classified these periods as the physical, emotional, and the intellectual stages. The first period, from twelve to sixteen, from an educational point of view, is the most critical and difficult to deal with on account of the secretiveness of the pupil. He does not care to express his feelings, and on the other hand, he is very sensitive. Habits are fairly well formed. It is true there is time to grow, but very little time for the formation of new habits.

At the beginning of this period, pupils begin to work in groups, team-work. It is the time when boys like to form groups and organize clubs. This leads to considerable physical exercise in the form of baseball, football, etc. From fourteen to sixteen is known as the "clumsy age," when the bones grow faster than the muscles. Some children during this period develop an awkwardness, periodic laziness with a tendency to self-assertion and dreams of greatness. Above sixteen years of age, the bones are formed to a considerable degree, and the student is able to handle tools on a commercial basis.

After the age of twelve the play period ends, and the growing boy begins to live in an adult world. He is moved by motives similar to those of adults. It is during this period that the sense of achievement becomes very prominent in some boys' lives. From twelve to sixteen is a time of the most rapid body growth, a great increase in the development of the muscles of the hand and in the control of accessory muscles. The tendency to imitation is renewed, and a strong desire to follow adult ideals and examples is formed. It is a period among many boys of greatest incorrigibility, misdemeanor, and crime, and of sensitiveness to ridicule. There is a keen sense of humor and a tendency to freakishness and pranks.

Children at about the age of twelve begin to differ more or less in strength, health, intellectual ability, capacity for motor-development, and other mental and physical qualities, to such a degree that any wholesale classification is out of the question. Nevertheless, we can divide children, roughly speaking, at about twelve years of age — any earlier period would be unreliable — into two groups based upon the progress in the traditional school system. Since the work at school is largely memory work, committing information received from books to memory, and the promotion test is based on this, most pupils who fail to pass this memory test lack the interest and power to commit to memory abstract information from books. All pupils who have attended school regularly, and who can measure up to the promotion test, may be considered, for want of a better name, *book-minded* or *abstract-minded*. Those who fail are called *retarded pupils*. A great many of these are of a sluggish mentality, strong physically, possessing the power of *imitation* and a mechanical ability, to a greater or less degree, and may be considered *motor-* or *hand-minded*. While this classification may be only approximate from a psychological point of view, nevertheless every grade teacher recognizes these two distinct groups — the *abstract-* and *motor-minded*. The interests of the hand-minded pupil are more motor than mental in character. It is from this class that industrial workers as a rule are recruited.

Adults and children show a greater difference in the control of firm and precise movements of the fingers than in the movements of the limbs. It is in this respect that the feeble-minded differ from the normal, the efficiency of the finer movements corresponding to a higher degree of intelligence.

All impressions received by the mind are recorded: we cannot always revive them. The easiest way to recall them is to arrange the knowledge in such a way as to be able to do this. Every exercise of the mind is dependent on attention, which is the concentration of nervous energy upon one group of brain cells. Upon the completeness of this concentration depends whether the mental exercise is more or less productive of knowledge and mental growth. Attention to its fullest degree requires the following conditions: calmness of mind, healthy organs of sense and thought, nervous vigor, and a healthy body. There is a great difference in the individual capacity for attention. Memory may be strengthened and trained by arranging ideas in such order as for one to excite the other, which means arranging according to one of the following:

Known to unknown.
Concrete to the abstract.
Cause and effect.
Means and ends.
Part and whole.
Like and unlike.
Object and subject.
Symbol and reality.
Dependent ideas.
Contiguous ideas.

Ideas in the mind are arranged in series; that is, one idea recalls another, etc. This arrangement is called the "association of ideas." In order to add another idea to human knowledge, it is better to attach it to some idea already in the mind than to present it as an isolated form of knowledge. The human mind is constantly arranging and rearranging the ideas, and this mental process is called reflection or "thinking." In order to get knowledge we must be able to retain it. Memory is the power of retaining knowledge. We have the power of mental acquisition and the power of mental conservation, which together give us knowledge.

Since all impressions leave a tract in the mind, they are indelible and can be recollected. Memory may be strengthened and trained by habits of concentrated attention and of association of ideas. The power for memory and recollection varies greatly in degrees, in different individuals, and at periods of life. Some men can easily commit facts to memory, but are able to retain them only for a short period, while others require more repetition and effort in retaining, but can more easily and for a longer period preserve the knowledge. Some minds have a stronger hold on facts, others upon thoughts and feelings; some have great difficulty in recalling names and dates and ease in recalling analogies. In early life the memory is very impressionable, but the impressions are easily effaced. Children seem very soon to forget knowledge obtained before the age of seven.

Therefore, in developing the power of memory train the mind to a vivid and complete recognition of all associated ideas.

Whatever a child does in school or elsewhere is actuated by a motive; that is, he does it for a purpose. The impulse — may be instinct or habit — pushes him forward. Any study that arouses the mind of the student so as to make him inquire about it, is said to be interesting to him. This interest may be aroused by the teacher and is said to be acquired. When the interest has not been aroused by the teacher, it is said to be natural. It is safe to say that no child can acquire knowledge who has no interest in it. A teacher can no more give a child an interest that he does not have than he can add to his own height. Interest may be aroused and the teacher should take advantage of the successive waves of natural interest which underlie instincts. One of the foundation stones of industrial teaching is to arouse interest which gives the motive for the acquisition of knowledge. Of course, it should be understood that no teacher should allow an undesirable interest or tendency to develop.

Every exercise of the mind is dependent on attention, which is simply a concentration of nervous energy upon one group of brain cells. Interests assist mental concentration. It is necessary in teaching a child to keep a sympathetic touch on his interests and previous experiences.

There is a great difference in individual capacity for attention. The best minds have not only a great grasp of attention, but a great facility for transition from one subject to another. In minds of universal power the readiness of transition is so perfect as to enable them to attend to several subjects at once, keeping different groups of brain cells at work and accomplishing various kinds of mental operations simultaneously.

If we examine our minds we shall see that the processes of accumulating knowledge consist in obtaining sense-perceptions, retaining them (memory) and comparing them, and forming a conclusion called "judgment." You might say that every sense-perception has a judgment.

To illustrate: a person interested in examining different metals, such as pieces of iron, brass, and lead, observes the qualities of each and naturally compares them. He classifies the metals either consciously or unconsciously into groups according to their common properties, such as color, weight, etc. He will say lead is heavier than iron, brass is different in color, etc. This act of classification rests on sense-perception and memory, but includes the power of holding a property or quality — that is, an abstract idea — before the mind for analysis or comparison. This power is called "abstraction," or the power of mental conception. In complex operations there is a series of judgments founded on a comparison of qualities and following a natural sequence of cause and effect, or evidence and conclusion.

Judgment becomes more and more complicated as the intellect advances in development. As we grow in experience and education, facts accumulate in the mind and knowledge increases, so that the field for comparison becomes larger. A greater number of relations and associations enter into our act of judgment. Definite judgments accumulate and form a fund of experience that can be relied upon as decision for further judgments, and may also become unconscious judgments that are often called "intuition." Of course we must bear in mind that in all complex mental operations there are series of judgments or decisions following a natural sequence of cause and effect. A series of judgments constitutes reasoning.

All who take part in every-day life are expected to have a minimum amount of good judgment that we often call "common sense." It is the result of common experiences which give intuitive judgment. Therefore, every one, particularly in this country, should have sufficient general education to have general intelligence and common sense. Life consists of a series of adjustments to new conditions. The power which enables one to make these new adjustments is called by the psychologist "apperception," and "gumption" by the experienced mechanic. One adjusts himself in terms of his previous experiences; that is, he apperceives new things in terms of his previous experience.

There are two methods of reasoning, inductive and deductive. The inductive is the natural method of reasoning. It reasons by examining a number of individual cases to discover a general resemblance or ground of classification and thus to reach the law or principle. The deductive reasoning begins with the rule or principle and draws conclusions respecting the individual case. The process by which we obtain knowledge, by committing general abstract rules or laws to memory and then applying them to special cases, is called "deduction." It is the method used by experienced students and teachers who claim that it saves time and can be easily learned. The inductive reasoning begins with facts and deduces the theory, and the deductive reasoning begins with theory and deduces the facts. Modern industrial education should proceed in the beginning as far as possible by the methods of inductive reasoning. While the operations of simple judgment, or one- or two-step reasoning, are common to all, the power of generalization is distributed in a larger degree over the abstract- rather than the motor-minded person.

There are two theories with regard to the training of the mind: formal training and specific training. Formal training theory, often called formal discipline or mental discipline, states that there are certain subjects, like mathematics and foreign languages, that give a general mental training such as logical reasoning power. The specific training theory claims that general mental discipline does not exist: that each subject has a mental disciplinary value that applies to that subject only, or one of similar content. Mathematics trains the mind for mathematical reasoning only. There is no question but that the theory of formal discipline is not true. On the other hand, there are some prominent educators who claim that the problem of training the mind is a complex one, and that the doctrine of specific training is only approximately true.

QUESTIONS FOR DISCUSSION

1. Why is a mechanic usually stronger physically than a professional man?
2. Name the special senses utilized by the following mechanics: (a) cabinet-maker; (b) steam engineer; (c) electrician; (d) worsted weaver; (e) jeweler; (f) structural-steel worker. Name some special devices used by the above mechanics to increase sense-perception.
3. What is the difference between an instinct and a habit?
4. What is the skill of a mechanic in terms of psychology?
5. Why is it more harmful to have acquired wrong manipulative skill than not to have acquired any?
6. What are the objections to allowing a child to receive industrial training under fourteen years of age?
7. What are the psychological effects of highly specialized occupations?
8. What are the moral and physical effects of extremely specialized occupations?
9. Does personal growth in character, physical power, and mental capacity depend upon the occupations followed?
10. Will early specialization on one who has not reached his growth have the same effect as specialization on one who has attained his growth later in life.

LIST OF REFERENCE MATERIAL FOR FUTURE READING

* *Educational Psychology*. E. L. Thorndike

(A very reliable book on psychology.)

* *Vocational Psychology*. H. L. Hollingsworth

(A very thorough and complete book on the application of principles of psychology to all vocational activities.)

* "Abstract-Minded and Motor-Minded." W. H. Dooley. In *The Education of the Ne'er-Do-Well*

(A distinction made between the normal boy and delinquent based upon ability to grasp academic subjects.)

* *Genetic Psychology*. E. A. Kirkpatrick

(A study of the psychology of different periods of growth.)

CHAPTER IX

GENERAL METHODS OF TEACHING

The previous chapter shows us that the human mind acquires knowledge according to certain principles, the most important of which are interest and progression. Interest varies with the different types of persons and at different periods of life. Progression means that the subject-matter we expect to impart must be carefully analyzed and separated into ideas, each one of which must be presented in the form of a lesson. Each idea must be the outgrowth of the preceding one.

Experience shows that there are two methods of analyzing the subject-matter: first, presenting the subject in complete units, and secondly, by considering parts of each unit separately. To illustrate: in teaching arithmetic the traditional arrangement was to present each unit completely, such as addition, before beginning the next unit, subtraction. The second was to present the addition of small numbers, then the subtraction, followed by the multiplication and division of small numbers. Then to return and consider the addition, subtraction, multiplication, and division of more difficult numbers. The first method is called the "unit" method and the second the "spiral" method. The unit method is part of the logical method of teaching, while the spiral method is based on the psychological method, that a learner can grasp the simple parts of a number of units of a subject more easily than the more difficult parts of any particular unit.

In teaching we should select the most economical and effective methods of conveying the information and skill or in presenting a subject. There are general methods and special methods of teaching. Experienced teachers usually divide the general method of teaching into five distinct steps: Preparation, Presentation, Application, Generalization, and Recitation or Inspection.

Preparation is the skillful manner in which a teacher finds out from the pupils what they already know on the subject. This is usually done by asking questions and recalling to the minds of pupils past experiences on this subject. Then show the value of more information and ideas on the subject by offering incentives. The mind is then eager for the new ideas that are to be grafted on the old ones. Present the additional information in an interesting manner. This step is called "presentation." The pupils should then be obliged to apply the new ideas in the class so that the teacher may see that they understand each step, "application." This work includes constant repetition called "drill." "Generalization" is the next step and includes the assimilation of the new and the old ideas so that deductions may be made. After the pupil has been taught and drilled, it is the aim of the next step, "recitation" or "inspection," to see that the pupil really understands the new ideas. This is done by written or oral examination or test, or by examination of the finished product in the shop.

The extent to which transfer of training or knowledge of one subject to another depends upon the organization of the course of study or the subject and upon the method of presenting the subject. A subject may be presented in such a way as to become an isolated group of principles, and arouse only a minimum of ideas in the pupil's mind. On the other hand, the same subject may be presented by other methods so as to arouse a great many ideas in the student's mind, and become part of his whole thinking. We may say then that the extent to which a pupil generalizes his training in a subject is a measure of the degree to which he has secured from the subject the highest form of training.

Instructors in teaching use different means of imparting information, such as lectures and demonstrations, use of textbooks, oral teaching, the laboratory, and objective methods. The lecture and demonstration method acts on the principle that the teacher should tell the pupil everything, and that he should not find out anything for himself. The disadvantages of this method are that the student may hear or see, but not understand; he does not learn how to think, discover, or develop the means of attacking a problem, to know how to get facts and other facts out of them. Despite the many disadvantages of the lecture and demonstration method, which applies mostly to technical subjects, a great deal of information, particularly of general education, may be and is imparted effectively through this method.

Most of the teaching carried on in school is through the assistance of specially prepared books for pupils, called "textbooks." This method of teaching was first introduced to secure uniform methods of teaching and to assist poorly equipped instructors. Instruction through books has the advantage that each pupil can think at his own rate, get the facts over and over again as he needs, and then test himself point by point and make note of his difficulties, which are to be explained by the teacher. Book teaching is very valuable to students who have the ability to get ideas from print. Some pupils who have the mental equipment, particularly the abstract-minded or scholastic type, prefer to read rather than listen to a story or a lecture. The motor-minded or practical-minded pupil prefers to hear the description from the teacher. Textbooks are valuable as a means of economy of time in teaching, as facts, principles, and applications may be given by means of a book in one month of the term of a course, and the rest of the term should be spent in study, experimenting, and problem-solving.

Personal teaching is largely oral. The value of oral teaching lies in the added interest due to the intonation, facial expressions, gestures, and illustrations used by the teacher. Oral teaching requires less effort on the part of the pupil than reading. It is very necessary to a certain age, particularly to the younger children. Oral teaching is very important in general teaching, in the art of questioning to determine quickly whether a student does or does not know, and also assists the teacher to verify the results of previous teaching. Dictation of a lesson requires greater effort on the part of the pupil than listening, because the process of writing is artificial and the characters are abstract and remote from the experience of the pupil.

There are certain elements of knowledge, particularly technical knowledge, that can be obtained only by direct experience of real things, qualities, events, and relations. The method of teaching through real things is called "objective" teaching, and may be given in different degrees; the actual object or thing, a model of it, a photograph of it, or a rough sketch of it. The laboratory method of teaching is a combination of the objective teaching with the observation and verification of principles involved by the pupil's own experimentation.

Efficiency in any subject or trade is only obtained by a continuous repetition called "drill." There are two methods of securing drill in school work: the *logical* order and the *psychological* order. The logical order consists of presenting first a series of exercises consisting of definitions and uses, composed of the elements of the subject formed by the analysis of the complete subject. The elements are combined and arranged in a series according to a preconceived principle of a teacher or an educator who has mastered the subject.

The advocates of the logical order believe that drills should be frequent and thorough, and should be continued until the pupil has acquired the habit. Without these frequent drills in the beginning, pupils may fall into bad habits and become discouraged.

The psychological order consists of presenting concrete facts of the subject to the student when he is actually curious about the facts or has been made curious by the teacher, who has aroused his interest by presenting incentives for the study of the subject. The student makes his own analysis as far as possible. Skill is not aroused by this method of exercises so well as by the construction of some useful or beautiful object that the pupil desires to make. When he finds that his skill is not adequate for this purpose, he may analyze the work and then strengthen by special exercises the weak elements, and finally apply himself again to the task.

The logical method is based on a theory that learning naturally starts with the elements into which a subject may be divided or analyzed, and that these elements may be built up by the mind into a so-called "logical" arrangement. While this is the method of rearranging knowledge in a scholar's mind after he has mastered the subject, it is certainly not the method by which a beginner or a learner arranges knowledge.

A great many people, particularly some prominent educators, object to the haphazard method of obtaining knowledge as practiced under the apprenticeship system and the home of old. The educator may say that it is not the economical method of learning. He fails to see that this natural method is not haphazard at all, but follows the mental growth of the pupil. Effort is obtained from the student as in the logical method, but it is obtained through a motive which a child must see in order to be interested. The experience of socicessful men who have been trained by the old apprenticeship system shows that this method gives a discipline that is deeper and more permanent than that obtained by other methods which have no relation to the person's self-development.

The attention paid to a subject — that is, the amount of mental activity involved — varies with the interest taken in a subject. The extent to which a person can be influenced by *deferred* or *remote* motives depends upon the period of growth of an individual and the type of the person. Motor-minded individuals are inclined to demand immediate returns: therefore, it is very important that this type of person should not be given considerable educational work (drills) of a drudgery nature in the beginning. Drill work should be provided just before it is necessary to have it. The interest or motivation of the present work is sufficient to carry the pupil over the preliminary drill.

Every instructor should carefully determine by experiment the amount of drill necessary for the proper acquisition of a habit. This amount is often called the "optimum" to distinguish from the least (minimum), or the greatest amount (maximum). Less than the optimum leaves the habit insecure and of little use. Greater than the optimum is a waste of time and effort. To illustrate: if you desire to teach a boy to make a wood joint, he should be drilled in making projects involving joints until he makes a satisfactory one to meet commercial conditions. After he has reached this stage it takes many hours of practice to add a very small degree of improvement.

The traditional public school system may be compared to a ladder reaching from the primary school to the college. It has one direction, preparation for college. It is divided into sections called "grades" based upon the chronological age of the individual. Pupils are graded in schools in order, as far as possible, to keep the mental and physical development in equilibrium. A great many children of the same chronologic age may safely be placed in the same grade in the school, up to the sixth grade, about the age of twelve. About this period individual children differ from each other in mental and physical development to a marked degree and a wholesale classification has proved to be inadequate. Any attempt to force the same course of study on all children above twelve years has caused a large percentage of retardation.

In the past, and in some cases to-day, the educational system has neglected the training of the motor-minded child who has certain mental and physical qualities that are required in industry. The course of study was laid out to favor those of a scholastic turn of mind who would eventually go to college. The test for promotion was a literary one and the intellectual type, with his quick memory, had no difficulty in passing the promotion tests, while the motor-minded child, without quick memory, fails of promotion and becomes what the teacher calls a "retarded pupil." He is asked to repeat the grade and he soon loses interest in school and feels as if he is a social outcast among the pupils.

An earnest effort is being made to-day to make the elementary- and the high-school curriculum broad enough to include every fundamental mode of utilizing mind which society employs in the conduct of its affairs; that is, at the completion of the sixth grade (about the age of twelve) a variety of courses, such as prevocational, commercial, and the regular school courses, should be offered to pupils. This will give to every variety of mind that interest and growth which are necessary to power and self-confidence in doing the day's work.

The teaching in our schools must also be modified radically in order to arouse the type of mind that will enter industry as a worker. In order to interest the student, problems to be studied must be made to arise in vital and natural ways, so that the child may recognize the need for all the school work which the teacher requires.

Schools should be so organized that ample opportunity may be given for studying and distributing the boys and girls into the particular courses of training and lines of occupation where each may do his best work. This has been desirable under vocational guidance. Opportunities should be provided for children who go to work to continue their education. Under a system of part-time schooling, as described on page 35, children will see the need of education of which they were previously unaware. Responsibility provokes thought and the need for more information and skill.

A course of study in the elementary schools should be sufficiently liberal to give the teacher opportunities for accurate inferences as to the industrial activity of the pupil.

There are five possible means of discovering the physical and mental qualities of a person for a suitable work:

1. General observation and recommendations.
2. Written examinations.
3. Trying-out process.
4. Controlled psychological tests.
5. Inference from school work.

Most applicants are engaged for positions in the trades and business, often on interviews supplemented by letters of recommendation. A number of employers look for a letter from the teacher or principal of the last school attended. The teacher, without any knowledge of the requirements for the occupation, is liable to place the academics above that of his mechanical ability, and recommend the type least suited for the work. This shows how important it is for the public school to know how to measure the ability of a pupil. To recommend a pupil for a position, we must know the pupil and the requirements of the position.

When a young man leaves school to-day, he looks for a position and is usually governed by the following conditions in selecting his occupation; initial high wage, his father's occupation, easy working conditions, and the nearness of the place of business to his home. He desires immediate rather than deferred returns. His parents fail to call to his attention the fact that positions that provide steady work, with a gradual increase of salary, seldom give a high initial wage.

The examination method is a tedious process and fails to give a true test of the person's ability.

The trying-out process of testing the ability of a pupil is an expensive method both to the pupil and to the manufacturer.

The psychological tests are in the experimental stage and have not reached the point where the average employer can perform the tests. It usually requires the experience of an expert.

The records of each pupil in school should give an index of the kind of work he is best adapted to pursue. To illustrate: Pupils with some artistic ability will display this talent in the fine art work that is carried on in the industrial arts, hand-work and drawing. There are very few pupils gifted with this talent, and it is very necessary that pupils should know before they leave school whether they possess this talent or not, the occupations that require it, and the opportunities provided for the development of the same. There are certain positions in the designing department of jewelery manufacturers, furniture manufacturers, cloth manufacturers, etc., that require this talent. Pupils may enter these trades and industries and work up to hold responsible positions.

There are certain characteristics that are necessary in every-day living for every mechanical occupation, and these are health, strength, and character. Boys of this type are usually found among the children of the families of the mechanical class. Boys of slight build should not be encouraged to go into manual occupations.

The craftsmen and skilled workmen should be recruited from the strong, healthy boys who show considerable ability in doing accurate work with the fingers and hands. This ability comes only after long experience and constant practice.

Vocational guidance may be imparted by the following means:

- Selected readings showing:
  - Economic activities.
  - Qualities demanded in various occupations.
- Systematic reading and study of prepared pamphlets.
- Individual or group conferences of pupils and teachers.
- Systematic study of young people:
  - Physical make-up.
  - Intellectual make-up.
- Prevocational training.
  - Systematic study of various economic lines of employment.
  - Maintenance of employment agencies.

QUESTIONS FOR DISCUSSION

1. What effect has industrial education on general methods of instruction?
2. Is the spiral system of presenting a subject used in high schools and colleges?
3. Some pupils would like to have the teacher do all the talking in class. Why?
4. How would you present the subject of decimals?
5. Give the outlines of a lesson plan on elementary science, properties of matter.
6. Has the lecture method of presenting a subject a place in the elementary school?
7. A large corporation provides lectures on popular subjects for working

people. Is this education? If so under which class would you classify this education? Why?

8. A college grade industrial school offers a course in English Literature for mechanical engineers. What type of education does this subject represent?
9. Children in the primary schools are taught hand-weaving. What type of education would you consider this subject under?
10. A boy of twelve (in a mill town) carries his father's dinner every day. While waiting for his father he sees the weavers at work and acquires a knowledge of weaving. Is this formal or informal education? Why?
11. Learning to read a newspaper is what kind of education?
12. What are the two great principles of teaching that underlie industrial work?
13. Interest depends upon what factors?
14. Do the so-called "general studies" in liberal education constitute a training in mental development of sufficient importance to be given in an industrial school?
15. Does the close application to practice and theory required in the training of a general electrician develop general intellectual powers, as attention, concentration, order, etc.?
16. Are there any strong interests that may be aroused by industrial studies which are frequently left inactive in general education?
17. Explain why boys are not wanted in the highly skilled trades until they are at least sixteen years of age
18. Is it more difficult to handle boys in the seventh and eighth grades than in the fifth and sixth grades? Why?
19. Which is more important, progression or interest?
20. Which is more efficient, individual or classroom instruction? Why?
21. Is it effective teaching to place a few illiterate non-English-speaking pupils of twelve years of age with the first and second grade pupils? Why?
22. Children in the lower grades are taught by objective teaching more than those in the middle and upper grades. Why?
23. Illustrate the difference between the spiral and unit method in teaching fractions.

LIST OF REFERENCE MATERIAL FOR FUTURE READING

* *The Learning Process.* S. S. Colvin.

(The psychological steps in acquiring knowledge.)

* *How to Think.* J. Dewey.

(The possibilities of developing scientific habits of thinking in children and adults.)

** *Principles of Education.* E. N. Henderson.

(A very complete book on the principles underlying modern education.)

** *How to Study.* F. M. McMurry.
(A discussion of the best methods of getting the child to study effectively.)
* *The Elements of General Method.* C. A. McMurry.
(A splendid book on general methods of teaching.)
** *The Primer of Psychology.* E. B. Titchener.
(A very elementary discussion of psychology.)

DIRECTOR OF INDUSTRIES
Bengal.
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CHAPTER X

GENERAL METHODS FOR TEACHING IN INDUSTRIAL EDUCATION

If we examine the successful engineer, mechanic, etc., we shall find that his knowledge consists roughly of three parts: the skill or manipulative phase, the related technical information that goes with the manipulative work, and a knowledge that promotes industrial ideals and general intelligence. To illustrate: the successful mechanical engineer has skill in running or operating mechanical plants and machines, a knowledge of parts of mathematics, physics, chemistry, and drawing which are the foundation stones of the practice, in addition to good intelligence and high ideals of his profession. The same may be applied to a house carpenter who has a large amount of skill in house construction and repairing; sufficient practical knowledge of such parts of mathematics, drawing, and science as to do his work intelligently.

A course of study or training in industrial education may be divided for purposes of instruction into three parts, the skill or manipulative phase, the related technical or theoretical information that goes with manipulative work, and the group of studies that are designed to promote industrial ideals and general intelligence. To illustrate: to teach a student to be a house carpenter means that he will receive a large amount of practice in house construction and repairing, also a study of such parts of mathematics, drawing, and science as a well-trained carpenter should know. In addition the student should be taught the history of the woodworking trades, distribution of occupations in this trade, and the special hygiene for wood-workers. A program for general intelligence in English, history, and civics should be provided. The amount of time devoted to the group of studies for general education should not be over twenty per cent of the total time allotment.

The manipulative skill in an industrial school must include training in the practical operations of that trade as carried on in a commercial shop. This may include, in the case of the general carpenter, manufacture of salable products, manufacture of school equipment and repairs on the building, etc., called "productive" work. As far as possible the school should manufacture articles that can be sold or used — commercial value. In this way it is possible, in addition to the profit from the sales, for a pupil to get the habit of making a commercial product that can be compared in both quality and quantity to the regular commercial product, and thus to arouse an additional interest on the part of the pupil. Non-productive practical work includes all work that cannot be put to practical use.

Every subject has two educational values, the practical and the theoretical. The practical value of a subject is acquired for a definite purpose. The ideal of the practical is personal efficiency, and the ideal of the theoretical is personal accomplishment or culture. The learning of mathematics, science, and drawing, as separate theoretical or abstract subjects, does not contribute to industrial education. It is the practical side of these subjects — that is, the correlation with practical work — that gives industrial efficiency. On the other hand, industrial education contributes some general education as a by-product. To illustrate: industrial training for a machinist includes a knowledge of metals, which involves some principles of chemistry, and shop practice, such as lubrication, speeds, etc., which involves principles of physics. In this way an industrial course for machinists gives an insight into the applications of principles of science. In addition, industrial education contributes to mental learning, on account of the close application to practice and theory, which tends to develop such intellectual powers as attention, concentration, order, etc.

The college grade school originally taught by means of lectures, textbooks, and demonstrations. As time went on, it was found that it was difficult for students to grasp technical knowledge from lectures and the printed page. Despite the fact that the student was interested in technical subjects and saw the importance of them, it was impossible to grasp the principles clearly. The laboratory method was then introduced.

The type of boy that is going to do the best work in a college grade school of technology is one that has the power to deal with applied science, mathematics, mechanism in the abstract. Some boys must have experience in order to understand the things, and cannot deal with the abstract problems in mathematics, science, etc., as easily as the purely abstract-minded boy. This type of boy is handicapped and therefore is at a disadvantage in pursuing this theoretical course. The schools of technology desire practically the same type of mind as the colleges, and the newer schools of technology follow the courses of study of the older institutions, with the approval of the alumni.

The two Russian schools of technology, one at Moscow, the Imperial Technical School, and the Institute at Petrograd, made valuable contributions to methods of teaching. They combined textbooks, lectures, and laboratory and shop practice. The work in laboratory and shop consisted of exercises in order to familiarize pupils with construction, use and nature of materials. Continental European schools have hesitated about adopting the Russian plan, but the United States and England have adopted it with much success in the schools of technology. The Continental European engineer is a technically trained scientist, and finds positions as designer, draftsman, and computer; therefore the school provides theoretical instruction for five or six years before going out into practical work; although at present a certain amount of shop practice is required before graduation.

While the instruction in the college and secondary evening technical schools follows somewhat the methods and content of the day courses, this does not apply to the elementary evening industrial courses. The type of pupil that attends the higher grades of evening technical classes is of a highly selected group, and has the interest and mental equipment to study a subject systematically and continuously for three, four, or five years. This is not true of the ordinary worker, as for example one who attends an evening trade school, with a poor general education and an intensely practical aim. They are unwilling to study systematically an entire subject, such as might be expected from children in a day school.

Both the inductive and deductive methods are used extensively in industrial schools. In the college grade or technical high school the general method of teaching shop practice is the deductive method; that is, from general principle to definite practice, or, as it is sometimes expressed, from the "how" to "why." To illustrate: a student in electrical engineering in a school of technology would begin his training by a theoretical discussion of the principles in science, mathematics, and drawing underlying the machine or job. Later in the course he would receive shop practice which would involve the principles he has studied in the abstract.

While there may be some justification for the so-called "abstract" and "logical" methods, supplemented by objective teaching, in higher technical schools, where the students are matured and possess considerable power of abstraction and linguistic ability, experience has shown that it is a very inefficient method for the motor-minded pupils from whom tradesmen and industrial workers are recruited.

The characteristics of the motor-minded boy are quite different from those of the abstract-minded boy who has profited to a large degree by general education. Motor-minded children usually have considerable physical activity, which shows itself in both "constructiveness" and "destructiveness," real desire to build things and to pull objects apart, to see how they work. They cannot sit still, and desire to move and handle the objects for the love of action.

The general mental activity of this type of boy leads him to "imitate"; the desire to do what older and experienced men do. Another instinct that is well developed is curiosity. The feeling to know what is "being done" and "how it is done" and "how it works" are valuable as a means of producing interest. While the interest may not always be sustained, it is of sufficient temporary character to be of value. It is surprising the amount of unorganized knowledge accumulated in every-day industrial life through curiosity.

The motor-minded boy is very easily discouraged if given a too difficult task. He immediately loses interest. Since confidence in one's ability to do a job is a very important factor in developing interest, it is very necessary to grade all work given to him in a progressive form of simple steps, so that one step is apperceived out of the preceding one, and that no step is too difficult. Then each success means greater confidence.

In addition he has an intensely practical, selfish mind. He is not able to think in deferred values; he desires knowledge and information that has immediate value to himself alone, and is not willing to study a subject systematically in the hope that it may be of value at some future date.

Therefore, in instructing this type of boy in industrial subjects, it is absolutely necessary that the instruction be adapted to his needs. All instruction must center around his selfish aim. In order to secure his interest it is necessary to arouse a feeling on the part of the pupil that the subject he is about to study will assist him in some way in something he wishes to do. No task must be beyond the ability of the pupil, so as to develop his self-confidence. After the task has been completed, some means of praise should be provided. This may be done by word of praise from a superior officer, by mark, or a roll of honor, or a prize.

Since the power of abstraction is not very great, it is important that all instruction should be concrete and objective. Concrete teaching usually gives immediate and not deferred value. Another value of concrete instruction over abstract or book instruction is that the former may be made into units, as simple as desired. This is not true in the case of book knowledge. Concrete instruction leads to self-confidence. The inductive method is one of the most effective means of teaching the average mechanic apprentice. The apprentice has considerable shop practice and wonders why he performs certain work, and the next time he attends class he usually asks the shop instructor the reason.

The average apprentice or pupil in an industrial school represents the same degree of intelligence as that of the mass of the population. A study of his characteristics will show that he is intensely selfish. You must study him in order to secure the best methods of teaching or presenting a subject to him. The first step is to secure his attention; second, to maintain his attention until you have developed interest; third, to develop the interest to a point where it results in action; and fourth, the teacher must guide this action into desired (efficient) results. The industrial school instructor succeeds in the same degree as he applies successfully the above methods to teaching.

The teaching lesson in industrial work may be divided into two methods: the information method for teaching shop-work and the development method for teaching trade technical work such as industrial science. The lesson may be presented according to the following steps: preparation, presentation, application, testing, and generalization. In teaching shop-work the first step, preparation, should include a direct review or statement of the aim by the teacher. The second step should include a demonstration, lecture, or illustration, or a continuation of the subject by the instructor. The third step, application, should apply the method, and the pupil follows it in doing the thing taught. The next step, testing, should be a test of the pupil's ability, which is usually given in the shop by assigning him a piece of work, or a recitation or examination (written or oral). The last step, generalization, leads the pupil, under the direction of the teacher, to generalize and to apply the lesson to many situations which are not similar. This step may not always be required. It depends on the advancement of the pupil. It is usually omitted in elementary work.

The first step in the development method includes brief questions or "key-words" to recall to the pupil's mind all information on the subject, that the new ideas may be "tacked" on to the old. Step two includes the experiment, demonstration, illustration, or combination. The application step allows the pupil to work out his own method and to follow it in doing the work taught. The next step is a direct test of the lesson on the job, or recitation or examination.

Since this type of boy is not naturally interested in the academic work related to his trade, the problem of presenting the academic subjects is a difficult one. The interest in academic work may be aroused by correlating these subjects with the practical work. To illustrate: every project, or in fact all shop-work, involves some principles of English, mathematics, and science. After the boy has worked on a machine, there is a natural curiosity to know something about it. It is then time to explain the principles of science in terms of the daily experiences of the boy on the machine. The same is true in regard to mathematics. A written report on the work of the day would be the basis of the English lesson. In this manner an incentive is offered to the boy which creates an interest for the study of English, mathematics, science, and history.[1]

This method of teaching, practice and thinking about the practice, is the way a great many young people, who have had difficulty in mastering abstract principles and themes as taught by the old book method of memorizing, have been able to grasp them: not only to grasp them, but to retain and comprehend them. The practice should always precede the theory, and the two should be intimately associated together so that both constitute an approach and a reinforcement.

The old-fashioned schoolmaster has been teaching the motor-minded child during adolescence on the logical basis, on the assumption that he could grasp the principles of drawing, pure mathematics, and pure science before the application. This was due to the fact that the mechanical arts and scientific subjects were taught after the methods of the colleges and professional schools, where pupils were abstract-minded and could be taught on logical lines. There may be some justification for abstract teaching, particularly the theory before the application, in the college and professional school, but there is absolutely none in vocational and prevocational schools which are preparing the motor-minded child for some specific vocation.

In fact technical schools of every type, including the colleges, are beginning to recognize that practice and thinking about the practice, in any given calling, must be closely related. Forty years ago the best medical schools provided courses in lectures supplemented by demonstrations by the teacher. The student performed little if any practical work in anatomy. To-day medical schools have laboratories, hospitals, and dispensary work to introduce the beginnings of practical experience. The same holds true for training in engineering schools, nautical schools, agricultural colleges, etc.

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[1] See pages 104, 105.

One of the most difficult problems in a vocational school is the question of discipline. The average teacher thinks his success depends upon a rigid organization with many rules. A successful industrial school is one that can train boys efficiently. In order to do this it is necessary to have an organization and some rules. Discipline is a means to an end. The success of the organization depends upon every pupil conforming to the rules and customs of the school.

The usual type of boy in an industrial school is inclined to do things in his own way and to question authority. Therefore the principal and teachers must have the ability to deal with this type of boy, to get along with him, and to win his confidence and respect. Then through kindness but firmness, the boy must be taught that habits of obedience must be formed. It may be mechanical at first, but it will become natural by experience and education. The pupil must be dealt with in such a way as to strengthen his character. Every case of discipline in a school is an individual problem, and must be settled as such through the coöperation of home, school, and the teacher, always remembering to strengthen the boy's character.

A skilled workman is the result of not only shop skill, but trade intelligence. He must not only know what he is to do, and how he should do it, but why he should do it. Why he is to do it involves a knowledge of the principles of English,

PLAN SHOWING RELATION BETWEEN SHOP PRACTICE AND RELATED TRADE SHOP INSTRUCTION

Total number of hours devoted to a job	Shop project or job	Purpose of project	Materials, etc.	Used	Hand tools	Used Hours on each tool	Power tools	Used Hours on each tool
200	Tool-room Handling tools Receive, stow, and issue new tools; repair them; all under the direction of the experienced mechanic	To become familiar with the tools of the ship-fitting trade. To note the condition of tools when issued new and their condition when returned, whether ill-used or abused, the best method of repairing tools for reissue; to decide when defective tools should be discarded	List of materials in stock-room		List of tools in trade		List of parts of power tools	

RELATED TRADE KNOWLEDGE

CLASSROOM INSTRUCTION

Shop English	Shop Science	Shop Mathematics	Shop Drawing
Practice in spelling and description of the various tools, etc., in the tool-room	Types and manufacturers' names of tools, etc ; use of tools, such as hammers, cold chisels, etc.	Practice in simple problems dealing with measurements involving the four fundamentals applied to the tools in the tool-room	Practice in making rough pencil sketches of tools, such as chisels, wrenches, hammers, nuts, bolts, etc.

mathematics, the science and drawing that are the foundation stones of the trade, and which are often called the related knowledge of the trade.

The aim of the course and the type of pupil both dominate to a large degree the course of study. The course for a skilled tradesman would be different from a course for a helper in the same trade. The same is true in regard to an industrial course in a college grade school of technology and in a trade school. The average type of pupil in a trade school may be described as follows:

a. Limited general education (average seventh grade).
b. Practical mind.
c. Dislike of regular school methods.
d. Must be aroused through greatest interest (his trade).
e. Looks for immediate returns in education.
f. Thinks only in one-step reasoning.

The methods of teaching must appeal to the type of boy.

1. Objective teaching
    a. An actual shop experience.
    b. The object itself; or,
    c. A model; or,
    d. Lantern slide; or,
    e. Picture; or,
    f. Diagram.
2. One-step reasoning.
    a. Series of questions, or problems in mathematics, sciences, etc., based on shop experience, etc.
    b. Discussion of questions and problems.
    c. Answers written in a book with sketches.
    d. Individual teaching.

Evening classes in industrial subjects represent one of the most effective systems of training those already at work. The most ambitious workers in every industry desire to obtain a practical education that will advance them in their vocations. The extraordinary success of the correspondence school in large cities is another indication of the desire of many workmen to improve themselves in their general vocations. Over sixteen hundred students were enrolled in these schools from one city of one hundred thousand inhabitants. The disadvantages of instruction by correspondence are many, but such instruction is better than none at all. There are thousands of men in every community intellectually incapable of benefiting by this course. Not more than three in one hundred complete their course; in fact the International Correspondence School admitted, in an article published a few years ago in the *American Machinist*, that but 2.6 per cent of their students have been awarded a certificate or diploma. The vast majority of men enrolling are soon discouraged and frequently lose faith in their work.

Evening industrial classes, in order to be most effective for the average worker, must be planned and organized on different lines from the day technical classes. The type of student attending evening trade classes, after a hard day's work, has an intensely practical aim in view, and is unwilling to study systematically an entire subject, as might be expected from young people in a day school. They demand that the instruction shall lead directly to the specific things they want to know. If they are obliged to spend a month or more on preliminary work, the value of which they do not know, they will soon become discouraged and leave.

Then again, mechanics and other tradesmen, who may, perhaps, have some reputation in their trades, and who wish to perfect themselves in certain technical lines, do not wish to be grouped with younger persons, feeling that such persons, having recently come from the public schools, are better able to answer questions, use better English, and appear to better advantage. In other words, adults are often sensitive about the comparisons which the younger members of the class are apt to make at their expense.

Every worker attends an evening technical class to satisfy a definite need. To illustrate: a young apprentice in a machine-shop finds difficulty in reading a blue-print. He enrolls in an evening drawing school to meet this need. The teacher is a mechanical draftsman, and he thinks the best way to know how to read a blue-print is to be able to make one. The young pupil is taught lettering, how to draw straight and curved lines, and to make simple drawings. The student's fingers are hardened from rough work and he finds it difficult to manipulate the fine drawing instruments. During all of this time he is receiving, in his daily work, the same reprimands, and is therefore debating in his own mind the value of the drawing course. It is undoubtedly true that the drawing course outlined by this teacher is a valuable one for teaching mechanical drawing to those who are to become draftsmen, but the average apprentice machinist, such as this young man, does not see the direct application of this instruction to his daily need. He enrolled in the drawing class for a definite purpose. To be sure, it was a narrow one, but, nevertheless, it had economic value to him. The training in mechanical drawing which a machinist needs is not the same as that of a draftsman. This young man shows that he needs a course in blue-print reading and in arithmetic for machinists.

Evening school instruction in technical classes should be divided into small unit courses so as to satisfy a definite need. Just what unit courses should be offered in a school may be determined by allowing one whole week for preliminary registration, that every worker may attend and talk over the educational needs of the different industries.

Instructors in evening industrial classes should be practical men and women, with considerable trade experience. Considerable shop practice should be used in applying the principles underlying the trade. The actual blue-prints, shop problems, and methods should be used in this course. Subjects that do not find continual application in the trade should be given in the advanced rather than in the elementary course. The instruction in the various branches of mathematics should be adapted to meet the needs of the machinist, the plumber, and the carpenter. The terms used in the schoolroom should be expressed in the language of the shop and the mill.

All technical students should be classified, as far as possible, into classes according to their trades; for example, a class in arithmetic for engineers and a separate class in the same subject for boiler firemen. Again, the textile designers should have a class in arithmetic, called "cloth calculations." This idea carries out the plan of the old trade guild of a few centuries ago. Each guild was formed for the purpose of social intercourse and mental stimulus. Each trade had its own guild. The daily trade experiences of each member became the property of all members. Discussions relating to the practices of their chosen trade occupied their attention. So to-day workmen have common interests. When evening students are grouped according to their occupations they have an opportunity to talk over their interests. The teacher should act as a leader, draw from the students discussions of their trade experiences, and through the expression of these various opinions solve the problems. It may be difficult to get students to recite and express themselves at the blackboard, but a free discussion of the point at issue makes the student lose his self-consciousness, and before he is aware of what he is doing, he is at the board illustrating his particular method of solution. Of course such discussions should be under the wise guidance of the teacher.

Trade training for helpers and semi-skilled workmen is more intensive than that provided for the skilled mechanic.

There are two reasons why this is true; first, the training necessary for the helper and semi-skilled worker is very limited, and requires practice in one or two operations only, as chipping and calking; secondly, these workers have intensely practical aims and desire a type of simple instruction bearing directly on their work, and they are not willing to study systematically the related branches of their occupations.

Courses for helpers vary from a week to six weeks in length, and consist of seven hours' practical trade instruction and a one hour talk, by the shop instructor, who is a skilled mechanic. In order to reduce the cost of instruction, the pupils usually practice together under the immediate direction of the shop instructor. For example, in teaching house carpenters to calk wooden boats a model frame with cracks is built. The carpenters practice, day after day, calking the seams, until they are able to do the work satisfactorily. The talk by the instructor consists of descriptions of tools, how to avoid the difficulties encountered, and the reading of a blue-print.

The method of imparting instruction to these men is best given through the question-and-answer form. Sheets may be prepared with the questions and answers on them and each helper given a sheet to read over. While this method of teaching has not the approval of the general educator, for many reasons it is the time-tried successful method of all short-term trade courses. It is the most effective method for this type of worker, and should be encouraged among short unit courses for helpers and the semi-skilled workers.

LESSON SHEETS ON INTENSIVE TRAINING IN STEAM ENGINEERING FOR ENGINEERS

QUESTIONS AND ANSWERS

Q. If you were called on to take charge of a plant, what would be your first duty?

A. To ascertain the exact condition of the boiler and all its attachments (safety-valve, steam-gauge, pump, injector), and the engine.

Q. How often would you blow off and clean your boilers if you had ordinary water to use?

A. Once a month.

Q. What steam pressure will be allowed on a boiler fifty inches in diameter, three-eighths of an inch thick, 60,000 T.S., one-sixth of tensile strength factor of safety?

A. One sixth of tensile strength of plate multiplied by thickness of plate, divided by one half of the diameter of the boiler, gives safe working pressure.

Q. How much heating surface is allowed per horse-power by builders of boilers?

A. Twelve to fifteen feet for tubular and flue boilers.

Q. How do you estimate the strength of a boiler?

A. By its diameter and thickness of metal.

Q. Which is the better, single or double riveting?

A. Double riveting is from sixteen to twenty per cent stronger than single.

Q. How much grate surface do boiler-makers allow per horse-power?

A. About two thirds of a square foot.

QUESTIONS FOR DISCUSSION

1. Some instructors in wood-working trade classes frequently begin with exercises intended to teach the boy the fundamental principles of construction. Explain the advantages and disadvantages of such a course.
2. Explain why some mechanics like the so-called "catechism method," question and answer. Does each question involve much more than a single-step reasoning?
3. Which is the easier to learn, how to run a lathe, or the mechanical principles underlying its working?

4. A superintendent of apprentices in a machine-shop makes a practice of writing personal letters to apprentices if they do good work, and a letter to their parents if the work is poor. Is this a good practice? Why?
5. Is it possible to devise a program of industrial education that would train all-round practical tradesmen?
6. A number of prominent technical educators contend that to-day there are certain studies and practices that serve as a basis for general industrial training. What is the objection to such a plan?
7. What arguments may be offered for urging a systematic industrial education in some trade requiring various operations, over a form of training involving a series of special operations found in a highly specialized occupation?
8. Visit an industrial school and note the difference in aim, method, and type of pupil from that of the regular high school.
9. To what extent and under what conditions do the results in practical experience in general — that is, skill, knowledge, appreciation, and ideals in one trade — constitute an advantage for entrance into another trade?
10. Does the experience of a well-trained machinist benefit him in any way when training to be a house carpenter?
11. To what extent does the general experience of a farmer's boy assist him when training to be a machinist?
12. Visit a number of different industries and trades, and notice the difference in physical development, ability to explain, etc., between the clerks (office help) and mechanics, highly skilled mechanics, helpers, etc. Classify them as "motor-minded" or "book-minded."
13. Explain the psychological reason why (*a*) a pupil who has learned to run a speed lathe will learn how to run an engine lathe more quickly than a pupil without any knowledge of either machine; (*b*) a pattern-maker's apprentice who has made a visit to the foundry and observed the work will learn how to "draw" a pattern more quickly than a boy who drives a grocery wagon; (*c*) a boy who has done some printing at home on a hand-press will understand the operation of a power-press better than a boy who has worked at wood-working; (*d*) a boat-builder will learn house carpentry quicker than a coppersmith.
14. Is it necessary for a pupil to have developed an industrial aim, desire to learn a trade, before entering an industrial school?
15. Why is it important that an industrial school should imitate industry as far as possible?
16. Is the college grade industrial school student usually as interested in the theoretical discussions of a machine as he is in running the machine? Why?

LIST OF REFERENCES FOR FUTURE READING

*_The Instructor, the Man and the Job._ Charles R. Allen.

(A splendid discussion of methods that may be used in teaching tradesmen.)

**_Principles of Secondary School Instruction._ Charles De Garmo.

(Splendid discussion of methods adapted for the adolescent.)

**_Methods of Teaching Industrial Subjects. Handbook of Vocational Education._ Joseph S. Taylor.

(Short discussion of methods.)

*_Organization and Methods of Teaching Vocational Classes._ Massachusetts Board of Education. Bulletin no. 3.

(A very fine discussion on methods based on experience in Massachusetts.)

*_Outline of Lessons._ Institute of Teachers. Bulletin published by Wisconsin State Board of Industrial Education.

(Lessons worked out by industrial school instructors in Wisconsin.)

CHAPTER XI

METHODS OF TEACHING SHOP-WORK

THERE are four distinct ways in which one may be trained in shop practice: first, by a mastery of the tools and machines of the trade; second, through developing a skill in the fundamental operations of the trade; third, through a knowledge or skill of working the materials of the trade; and fourth, developing skill in the application of the principles of metal-working.

The first method is generally used in the mechanical engineering department of a college or a technical school of college grade. The instructor teaches the student the theoretical principles on which each tool and machine is based. In the machine-shop trade, it would include the theory of cutting-speed, principles of each hand- and power-tool, supplemented by the mathematical problems underlying the work. After the student has received this instruction, supplemented by a diagram or blue-print, he is sent to the school shop to receive training in the practice. The purpose of this instruction is to give the student who has the capacity to deal with abstract technical knowledge a training in both the practice and theory of machine-shop work. He is to use this knowledge as an expert, designer, etc., not as a journeyman. The shop-work is usually a series of exercises to illustrate a principle. The method of imparting this instruction is from general principles to definite practices in the shop, and gives very good results for the type of school.

The second method has always been used effectively in training apprentices to be journeymen. The students are taught by coming in actual contact with shop conditions.

In the machine-shop they have experience on the different machines, doing actual commercial work; they see that cutting-speeds are used on certain metals, and learn how to use the various devices. They learn by practice the mechanical parts of the machine first without the theoretical principle involved. This method of teaching is from definite practice to abstract principle.

The steps in teaching a lesson in shop-work may be divided into four parts: first, getting the young apprentice started thinking about the new trade which he is about to take up, trying the unfamiliar things, presently to be imparted, with the things he knows, in general arousing his interest and winning his confidence. This step may be called the "preparation." The master or skilled mechanic does this in many ways; by asking the learner many questions which lead him to think about the new work, then demonstrating work with tools or showing him finished work and explaining its nature, or by relating interesting illustrations drawn from the experience of the master or skilled mechanic.

After the way has been prepared by leading the apprentice to think about his new work, and interesting him in it, a simple but definite operation of the trade practice is explained to him, and he is expected to carry it out, which is step number two, presentation. The apprentice is next allowed to carry out the simple operation under actual commercial conditions, the instructor supervising the work. This step is called "application."

The next step is testing the subject-matter of the lesson. During this step various errors in teaching crop out. For example, attempt to teach too much at one time, failure to make each teaching step plain before starting on the next, lack of patience, tact, or interest. The instructor should make an attempt to find out why the student fails, and should then try to improve upon his own teaching.

Where an instructor is obliged to teach shop-work to a class of fifteen or more pupils, the steps in presenting a lesson are as follows: demonstration by the teachers, practice steps by the pupils, and the tests given by the teachers. The demonstration includes the preliminary talk to the pupils on such points as the common names of tools, uses of tools, blue-prints, or sets of patterns, measurements or steps in shop practice, etc. The industrial interest in the pupil is sufficient to hold the attention. The practice steps should follow the demonstration, and should consist of one pupil performing the work under the direction of the teacher, in the presence of the class. The teacher should correct all mistakes made by the pupil and offer suggestions at the same time. The mistakes made by the pupil represent the common mistakes, and should be listed on the blackboard as such. This step is an economical device to save the teacher repeating all corrections to every pupil. The last step should be a test given by the teacher to the pupils. The teacher should follow each pupil's work and give individual instruction. Scrap pieces of stock, etc., may be used for drill purposes on certain points that the pupil fails to grasp. Pupils should be taught as of old on projects that have commercial value, and the instruction should be carried out in a commercial way. This is very necessary, for the habits the pupils form are the ones they will use; therefore develop commercial habits. Develop the habits of skill in the way they are to be used.

Thus we see the most effective means of producing skill is to secure interest (industrial); then explanation, example, and drill follow. Example is better than rule; imitation more effective than explanation.

Many industrial teachers make a grave mistake by explaining rather than showing to the motor-minded type of child. Imitation is one of the strongest instincts and should be utilized to greatest advantage. The instructor should not insist too strongly on a particular method. Remember there are various ways of performing an operation; one method may be good for some, others may profit by a different method. To attempt to force students to use the same methods is a terrible waste of energy to some pupils.

One of the first questions that come before a shop instructor in an industrial school is, How shall I arrange my shopwork so as to give the pupils the most efficient and economical course? As we saw on page 25 the average mechanic obtains his trade in an unorganized manner, often by stealing it. Under this last method there is no question but that there is a terrible waste going on in training mechanics. The most effective system of teaching a trade to those who are about to become journeymen is to assign to each pupil a series of jobs arranged in a progressive order. The simplest job is one that involves the fewest elements of mechanical control regardless of the number of operations. Since there are simple and difficult operations in each machine, it is clear that the spiral and not the unit method should be used. In the machine-shop trade drilling on an upright drill, with template, then with jigs and fixtures, may be considered as a good beginning. Rough work may be given to a beginner, in which the operator removes considerable amount of material with leeway with regard to dimensions, such as turning down square bar stock to rough round in a lathe. The finishing cuts may be given to the advanced students. Complex work that demands considerable judgment, setting-up work on milling machines, etc., are generally given to the advanced students.

In order to hold interest and retain a high standard of skill, it is absolutely necessary to have the pupils work on real jobs having commercialized value: otherwise the shopwork standard will be low and consist of a series of routine performances. The pupil does not have the interest and lacks initiative in his work under these conditions.

The training of students for shop practice should be carefully planned so that the apprentice may receive an all-round shop experience, and not be held on any one type of work at the expense of his training in other phases of work in his trade. This has been one of the most difficult pedagogical problems in industrial schools, especially those laying great stress on productive work, as corporation apprentice schools. A shop for teaching apprentices is usually laid out to do commercial work and the foremen and other leading men are hired on their ability for shop production. There is a great temptation for both the officials and mechanics to keep apprentices on work that they can do to the advantage of the shop. Therefore it is absolutely necessary, in the interest of the proper training of the apprentice, to have a card made out showing time allotment in hours or months, in the different lines of work practiced in the trade. It is possible for the apprentice to record the time spent on each type of work, that he may see the progress he is making. In case the student is being used as a helper on highly specialised work, or kept too long on one class of work, he can appeal to the master of the trade. The officials are able to record the work of the boy to better advantage.

The training of an apprentice in the shop practice of a trade should include, among other things, the following:

At least one month in the tool-room handling tools under the direction of an experienced hand. The student should be taught shop and manufacturers' names of the tools, the difference between the condition of tools when issued and their condition when returned. In this way he will become familiar with the defects of tools, know how to repair them, and to decide when tools should be discarded.

At least one month in the stock- or fitting-room under the direction of a skilled mechanic, who will teach the boy the names of the different kinds of stock and fittings. At an early period of course the apprentice should perform the menial and disagreeable part of the trade requiring little training or skill. For at least one year the apprentice should be under the guidance of the trained men so as to prepare well for the time when he will be thrown on his own resources. He should be trained in work that will develop responsibility and accuracy, care in the operation of expensive or heavy machinery.

One month during the last year of the apprenticeship should be spent in the estimating department to show the need of economical work, with regard to the cost of labor, time, and material. The most difficult part of the work should be completed during the last year. This work should be done entirely from plans and develops responsibility.

The apprentice or student should pursue his course according to conditions advantageous both to the student and to the employer. He should first learn the names of the tools, then work with an experienced mechanic, and later be allowed to work alone under a foreman or supervisor. To illustrate: if it is desired to have a course for a machinist's apprentice, it is first necessary to determine the kind of work and the machines necessary to do the work efficiently. The following represents the different kinds of work; stock-room, tool-cribs, forge-work, bench-work (filing), lathe practice (speed and engine), drill-press work, plain milling-work, cylindrical grinding, surface grinding, screw machines, planer and shaper, small-tool manufacturing (reamers, cutters), hardening, tempering and heat treatment, tool manufacturing (jigs, fixtures), punches and dies, general repairs, general manufacturing, and assembling parts.

The accompanying card shows a form that is sometimes used to keep a record of the apprentice's shop experience or

RECORD CARD

NAME ____________________
RESIDENCE ____________________

TRADE ____________________
CHECK Nº ____________________

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	CYL.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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2																			
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practice. The content of the trade practice should be divided into a series of machine, tool, and shop practices. After each unit of the series the number of weeks' practice necessary to make the apprentice efficient should be placed. For example, the series of units for an apprentice course in machine shop-work might consist of the following:

Order	*Kind of work*	*Time in weeks*	*Year*
1	Stock-room	4	
2	Tool-crib	4	
3	Forge-shop	4	First year
4	Bench-work	8	50 weeks
5	Lathes, speed and engine	16	
6	Drilling	10	
7	Milling, planer	$16 \begin{cases} 4 \\ 12 \end{cases}$	
8	Cylindrical grinding	8	Second year
9	Surface grinding	8	50 weeks
10	Screw machines	12	
11	Planer, shaper	$16 \begin{cases} 10 \\ 4 \end{cases}$	
12	Small-tool manufacturing	16	Third year
13	Hardening, tempering	10	50 weeks
	Heat treatment		
14	Tool manufacturing jig fixtures	$16 \begin{cases} 12 \\ 4 \end{cases}$	
15	Punch and dies	16	Fourth year
16	General repairs	12	50 weeks
17	General manufacturing	10	
18	Assembling	8	
		200 weeks	

A working week consists of 48 hours making 200 × 48 = 9600 hours in the complete course. Each week a record should be made, on a weekly shop record sheet, of the time spent by each apprentice on the different kinds of work.

A formal report should be made every six months of the apprentice's shop-work and his related class instruction.

WEEKLY SHOP RECORD SHEET

TRADE

Name ______________________ Check No ______________________

Week Ending ______________________

Date																				
SUBJECT	Days	Dept.	Days	Dept.	Days	Dept.	Days	Dept.	Days	Dept.	Days	Dept.	Days	Dept.	Days	Dept.	Days	Dept.	Days	Dept.
Stock Room																				
Tool Crib																				
Forge Shop																				
Bench Work																				
Lathes																				
Drilling																				
Milling																				
Cyl Grinding																				
Surf "																				
Cutter "																				
Screw Machines																				
Planers, Shapers																				
Small Tools																				
Heat Treatment																				
Tool Making																				
Punchings, Dies																				
Drafting Room																				
Assembly																				
Miscellaneous																				

This record should be placed on the apprentice's life card, which is a permanent record of the school and should be kept by the supervisor of apprentices.

The apprentice shop report should include, in addition to work done, a mark of either very good (A), average (B), or unsatisfactory (C), on the following characteristics, speed, reliability, workmanship, industry, initiative, tact, aptitude, analytical ability, knowledge, enthusiasm, personality, and decision. It would also be valuable to have a record showing in what "he excels" or "is deficient."

A pupil or apprentice in a vocational or an apprentice school should be graded according to the standards of a successful mechanic. To illustrate: a successful all-round machinist should possess the following qualifications: adaptability, speed, be able to do good work (quality), be reliable (conduct), and punctual (regular in reporting for work).

A pupil or apprentice should be rated monthly in these characteristics. The mark may be expressed in percentages:

Excellent . .	95–100	A
Very good	90– 95	B
Good . . .	85– 90	C
Fair.	80– 85	D
Passable .	70– 80	E
Failed	Below 70	F

Lesson sheets should be prepared on machines with the parts marked with numbers. The names corresponding to the numbers may be placed to the right. Pictures or illustrations on lesson sheets showing the operator tending the machine, may be given to the pupil. There may be questions on the illustration as follows:

What is the name of this machine?
How is the power furnished to run the machine?
Name the parts of the machine that you can see, and tell the use of each part.

PERMANENT RECORD CARD

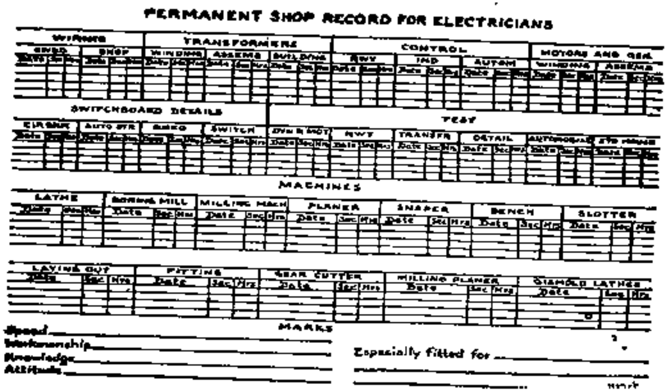
NAME **TRADE** **CHECK**

WEEKS	Stock Room	Tool Crib	[illegible]	Bench Work	Lathe	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Screw Mach	Planer & Shaper	Small Tools	Heat Treat	Tool [illegible]	Punch & Dies	[illegible]	[illegible]	Misc
1																			
2																			
3																			
4																			
5																			
6																			
7																			
8																			
9																			
10																			
11																			
12																			
13																			
14																			
15																			
16																			

The number of the department should be placed in the square corresponding to the day of the week he worked in that department

Speed__________________
Workmanship______________
Knowledge________________
Attitude_________________

Especially fitted for____________
______________________work



PERMANENT SHOP RECORD FOR ELECTRICIANS

WIRING						TRANSFORMERS									CONTROL									MOTORS AND GEN.					
GRND			SHOP			WINDING			ASSEMB			BUILDING			RWY			IND			AUTOM			WINDING			ASSEMB		
Date	Sec	Hrs	Date	Sec	Hrs	Date	Sec	Hrs	Date	Sec	Hrs	Date	Sec	Hrs	Date	Sec	Hrs	Date	Sec	Hrs	Date	Sec	Hrs	Date	Sec	Hrs	Date	Sec	Hrs

SWITCHBOARD DETAILS												TEST																	
CIR BRK			AUTO STR			RHEO			SWITCH			DYN & MOT			RWY			TRANSFR			DETAIL			AUTOMOBILE			STD [illegible]		
Date	Sec	Hrs	Date	Sec	Hrs	Date	Sec	Hrs	Date	Sec	Hrs	Date	Sec	Hrs	Date	Sec	Hrs	Date	Sec	Hrs	Date	Sec	Hrs	Date	Sec	Hrs	Date	Sec	Hrs

MACHINES

LATHE			BORING MILL			MILLING MACH			PLANER			SHAPER			BENCH			SLOTTER		
Date	Sec	Hrs	Date	Sec	Hrs	Date	Sec	Hrs	Date	Sec	Hrs	Date	Sec	Hrs	Date	Sec	Hrs	Date	Sec	Hrs

LAYING OUT			FITTING			GEAR CUTTER			MILLING PLANER			STANDARD LATHES		
Date	Sec	Hrs	Date	Sec	Hrs	Date	Sec	Hrs	Date	Sec	Hrs	Date	Sec	Hrs

MARKS

Speed __________

Workmanship __________

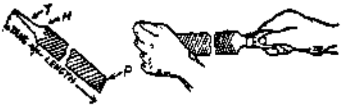
Knowledge __________

Attitude __________

Especially fitted for __________

What is the name of the operation?
How is the stock held in the machine?
Name the different attachments of the machine on the wall and floor?

Illustrations showing the position of tools may be displayed and questions asked about the use of the tools. For example: the following shows the position of a file and questions that may be asked.



What is a file?
For what purpose is a file used?
How is a file made?
Of what metals are files made?
What is the tang of a file?
Name the other parts of a file.
Why is a file sometimes curved instead of being flat?
How should a file be grasped?

QUESTIONS FOR DISCUSSION

1. If an instructor in wood-working gives exercises followed by an application of these exercises, in the form of production, does this method constitute good shop training? Why?
2. Give a unit of instruction for the following trades: house carpentry, machine-shop work, plumbing, printing, and electrical work.
3. Give a list of units in machine-shop work based on the unit progression; on special progression
4. The pupil as soon as he enters a trade school desires to wear overalls. Why?
5. Why will an apprentice house carpenter learn to read house plans and take off quantities of material from the plan, more so than would a dry-goods salesman.
6. Should an apprentice make solder before learning to wipe joints? Why?

7. A pupil between the ages of fourteen and sixteen desires to learn steam engineering; would you teach him to fire first or read the water glass?
8. A pattern-maker should know something about foundry work. One instructor suggested starting the pattern-maker in the foundry; another said let him go in after his first year of study. Which is right, and why?
9. Apprentices are often called upon to know about subjects they have not worked upon, but have seen. Is this just to the apprentice?
10. Apprentices are obliged to ask mechanics the names of tools. Is this a good plan?
11. Is it possible for a skilled mechanic who is teaching shop-work in the school every day, to lose the manipulative skill required in the shop practice?
12. A boy is kept a definite time on each machine in a machine-shop course. Is this good teaching?
13. A teamster and an apprentice machinist were both admitted to an evening machine-shop course. Which one will make the greater progress? Why?
14. If you were asked to teach a group of boys how to run a lathe, how would you proceed?
15. A survey of the existing methods of teaching shop practice in school and life would show the following:

a. Under the old-fashioned apprenticeship system the skilled journeyman showed the apprentice how to do the work.

b. The evening trade school instructor tells his pupil, who has already received some shop training, how to do a piece of work.

c. In many mechanical establishments the apprentice helps the skilled mechanic, and is expected to observe how a job is done.

d. In short-term private trade schools with limited facilities the pupil, with very little practical experience, simply observes how a job is done.

e. In a first-class apprenticeship system, in a private corporation, the apprentice does the job under the direction of a shop instructor, who explains the reasons why.

f. Many apprentices learn their trade by applying to a shop as a mechanic, and performing the work without any direction or assistance.

g. Apprentices sometimes are obliged to read from a book of shop practice how a job is done.

h. Some secondary industrial schools have the pupil perform the job in the school shop, and then make a drawing of it.

i. Industrial schools of limited equipment teach pupils from a book on shop practice, reading from the book and then reciting. Explain the advantages and disadvantages of each method.

LIST OF REFERENCE MATERIAL FOR FUTURE READING

* *Organization and Methods of Teaching Vocational (shop) Subjects.* Massachusetts State Board of Education. Bulletin no. 3.

(A discussion of methods of teaching for shop-work as worked out in Massachusetts.)

* *The Instructor, the Man, and the Job.* Charles R. Allen.

(A discussion of methods that will apply to all forms of shop-work, especially the commercial shop.)

* *Part-Time Trade and Industrial Schools.* Bulletin no. 19.

** *Buildings and Equipment for Schools and Classes in Trade and Industrial Subjects.* Bulletin no. 20. Federal Board for Vocational Education, Washington, D.C.

(These publications represent the latest thought on the subject of organization and methods of teaching.)

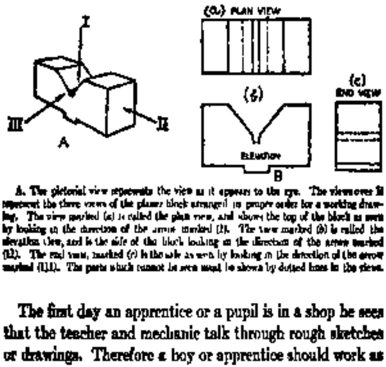
CHAPTER XII

METHODS OF TEACHING INTERPRETATION OF BLUE-PRINTS AND SHOP SKETCHING

THE language of shop practice is the blue-print. Directions are given to a mechanic on a blue-print, which consists of drawings representing the work the mechanic is to perform. Therefore every mechanic should be able to interpret a blue-print. In addition, he should be able to express his mechanical ideas on paper in the form of a sketch.

The drawing that an apprentice will need for his trade is quite different from that required by the draftsman in the same industry. A journeyman primarily requires the knowledge to read a blue-print, to look for dimensions, lay-out of holes, and to be able to make rough drawings of the work. A draftsman requires the ability to design, which necessitates the power to think in the abstract. Some very successful teachers provide the same course in mechanical drawing for the apprentice machinist and the apprentice draftsman. They fail to consider the difference in purpose of the two courses, and the different types of mind, which require different methods and content. While there may be some justification in teaching exercises in drawing lines, for the abstract-minded pupils, who desire to learn mechanical drawing, and who take education on faith, it is not the method for the pupil of intensely practical mind, who desires to know how to make a drawing in order to assist him as a mechanic. What is gained in technique by the exercise method is overcome by the lack of interest and failure to make proper connections. The practical-minded pupil is more interested in an object he is drawing than in the method of drawing.

Courses in drawing for apprentices or trade students in a vocational school should begin with sketching pictorial views of simple tools, appliances, etc., drawn by means of an ordinary school rule and simple school compass. Then show that it is necessary to have more than one view to bring out all the details. These views may be obtained by drawing one side of the object at a time. Each side is called a view. Usually three views are required to bring out all details — the plan, elevation, and end view. The following sketches of a planer block for machinists will illustrate the views.

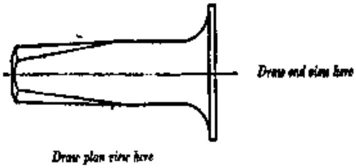


A. The pictorial view represents the view as it appears to the eye. The views over B represent the three views of the planer block arranged in proper order for a working drawing. The view marked (a) is called the plan view, and shows the top of the block as seen by looking in the direction of the arrow marked (I). The view marked (b) is called the elevation view, and is the side of the block looking in the direction of the arrow marked (II). The end view, marked (c) is the side as seen by looking in the direction of the arrow marked (III). The parts which cannot be seen must be shown by dotted lines in the views.

The first day an apprentice or a pupil is in a shop he sees that the teacher and mechanic talk through rough sketches or drawings. Therefore a boy or apprentice should work as soon as possible from a sketch or drawing. He soon learns to look to the drawing for information; that there are certain forms in which this information is put, dimensions, different views, kinds of materials, etc.

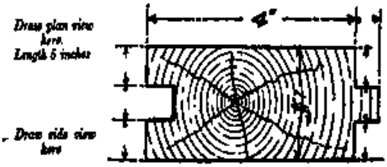
Put information in form by simple shop sketches (freehand or mechanical) that carry the data. Be sure the sketch contains all the points regardless of crudeness of form at finish.

Lesson Sheet on Drawing Square Flatter for Blacksmiths without dimensions

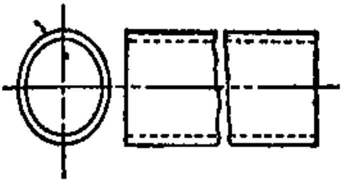


Square Flatter

Lesson Sheet on Drawing 1½ inches Matched Flooring for House Carpenters



Lesson Sheet on Drawing a Boiler Tube for Boilermakers



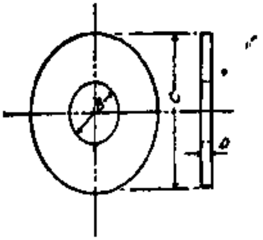
Boiler Tube

Draw one size of Boiler Tube from Dimensions of following Table

A	*B*	*C*	*D*	*E*	*G*
1½ in.	.393	1.767	.095 in. .109 in.	.419 .480	13 12
1¾ in.	.458	2.405	.095 in. .109 in.	.404 .566	13 12
2 in.	.524	3.142	.095 in. .109 in. .12 in.	.589 .664 .709	13 12 11
2¼ in.	.589	3.976	.095 in. .109 in. .12 in.	.643 .739 .805	13 12 11

A = Outside diameter.
B = Square feet of heating surface per foot of length.
C = Area of section in square inches.
D = Thickness of tube in inches.
E = Area of metal in square inches.
G = Birmingham wire gauge.

Lesson Sheet on Drawing a Standard Washer for Shipfitters



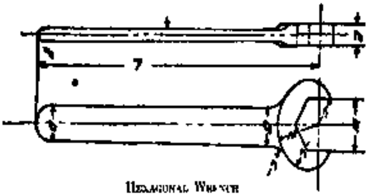
STANDARD WASHER

A is Diameter of Bolt

Draw two Sizes of Washers from the following Table

A	B	C	D
¼ in	5/16 in.	¾ in	.065 in.
⅜ in.	7/16 in	1 in.	.083 in.
½ in.	9/16 in.	1½ in.	.12 in.
⅝ in.	11/16 in.	1¾ in.	.12 in.
¾ in.	13/16 in.	1⅞ in.	.12 in.
⅞ in.	31/32 in.	2 in.	.134 in.
1 in.	1⅛ in.	2½ in.	.160 in.

Lesson Sheet on Drawing a Hexagonal Wrench



HEXAGONAL WRENCH

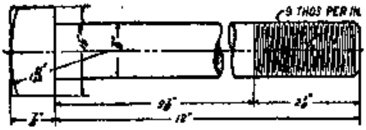
Draw one Size of Wrench from Dimensions in Table Showing Wrench Proportions

B = W × .8
D = W × .65
E = W × .4
F = W × .25
L = W × 7
A = Size of nut

A	*W*	*B*	*D*	*E*	*F*	*L*	*C*
5/8 in.	1 1/16 in.	7/8 in.	11/16 in.	7/16 in.	1/4 in.	7 7/16 in.	5/8 in.
3/4 in.	1 1/4 in.						25/32 in.
7/8 in.	1 7/16 in.						27/32 in.
1 in.	1 5/8 in.						15/16 in.
1 1/8 in.	1 13/16 in.						1 1/32 in.
1 1/4 in.	2 in.						1 5/32 in.

Complete this table

Lesson Sheet on Drawing Conventional Threads:

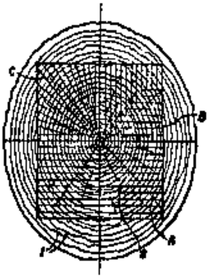


SQUARE HEAD BOLT

NOTE: Bolt is too long for sheet and is shown with piece broken out.

Make the threads as shown above. This is not supposed to be a true representation of threads but is one of many short cuts to save time. These are called conventional methods.

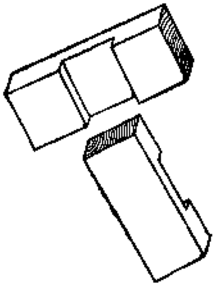
Lesson in Drawing Showing the Method of Sawing



1 = Circles of Growth.
2 = Medullary rays.
A = Bastard sawing.
B = Method of quarter sawing.
C = Best method of quarter sawing.

Draw the above figure about twice this size

Lesson Sheet on Drawing a Matched Joint

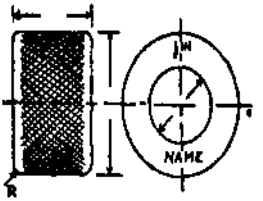


Draw the above figure as shown and make another view showing pieces assembled

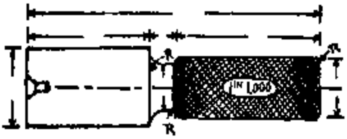
Problems in Drawing

1. Make a free-hand drawing of the following:

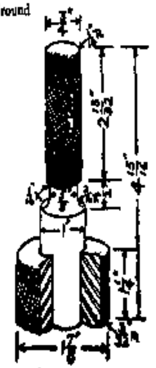
(*a*) Knife switch
(*b*) Globe valve
(*c*) Faucet
(*d*) Link trap
(*e*) Lathe dog
(*f*) Hexagonal head bolt
(*g*) Soldering iron
(*h*) Funnel
(*i*) Micrometer
(*j*) Screw driver
(*k*) Claw hammer
(*l*) Cold chisel
(*m*) Twist drill
(*n*) Reamer



ONE-INCH RING GAUGE — T. S.-Hard & Ground



ONE-INCH PLUG GAUGE — T. S.-Hard & Ground



From the above sketch draw 1-inch plug and ring gauges. Center hole .078" drill and [illegible]" counter-sink. Stamping Spot [illegible]" × [illegible]".

Questions

1. What objects are represented?
2. Of what material is it made?
3. What is the outside diameter of ring gauge?
4. What is the inside diameter?
5. Make a working drawing of the ring gauge and show all lines including hidden lines, with all dimensions required.
6. What is the length of the plug gauge?
7. What is the largest diameter of the plug gauge?
8. Give other diameters if any.
9. Make a working drawing of the plug gauge showing end view and all necessary measurements.

General Course of Study-Interpretation of Drawing

First Year

One month: Short, simple explanations of the purpose of the course and the value of it to an apprentice.

Free-hand isometric (or perspective) sketch of a rectangular piece of stock or part used in the shop. Drawn from copy without dimensions. Sketch of any other rectangular parts drawn from copy without dimensions. Then unit dimensions.

Free-hand sketch of parts containing curved lines. Use rule for measuring only. Blank stock, nuts, bolts, washers, rivets, screw threads may be used.

Four months: Introduce lettering. Rough pencil sketches of files, chisels, wrenches, various kinds of hammers, appliances, heating furnaces, shape of stock used. Mark names of parts of tools.

Four months: Drawing of shapes of stock in two views to develop the idea of projection (plan and elevation). Also views of stock assembled in two parts.

Three months: Sketches of parts of vessels, or boats, or stock, or engines, or motor, or dynamos, or wiring, etc.

Second Year

One month: Drawing of simple parts of the machines used in the shop as pulley, levers, spindles, gears, cutting heads, etc.

Three months: Reading of simple blue-prints such as used in the shop; dimension of parts, distance between centers, etc.

One month: Drawing of simple parts of machines used in shop involving two views.

Three months: Applied geometrical construction to practical work in the shop such as inscribing hexagons or erecting perpendicular, bisecting angles, reproducing angles, division of *pitch* circle or other problems.

One month: Practice in drawing assembled parts more difficult than before.

Three months: Practice in drawing assembled parts introducing the idea of simple shapes expanding into irregular surfaces.

Third Year

Six months: Apprentice may begin to ink in drawings, trace and make a blue-print. Drawing of two views of parts of machines. Sectional views.

Five months: Practice in making drawings from data or sketch of parts made in shop and show how installed.

One month: Practice in making drawing of complete machines, or parts of ships or boats to show knowledge of mechanism working and construction.

Course of Study in Interpretation of Blue-Prints for Shipfitters — Three-Year Course

First Year

One month: Practice in making rough pencil sketches of nuts, bolts, rivets, screws, washers, taps. Both isometric and plan and elevation views.

Four months: Practice in making rough pencil drawings of tools such as files, chisels, wrenches, various hammers, appliances and metals; heating furnace; oxygen acetylene set, etc.; simple plates, rivets in section, angle bars, tee bars, Z bars, channel beams in two views to develop the idea of projection. To illustrate: rivet spacing, design in one view should be given to illustrate simple connections, that is, a deck to a bulkhead, bounding bars, etc., in watertight, non-watertight and oil tight bulkhead spacing. Various types of rivets in plates (in section).

Four months: Pencil drawings of shapes of T's, I's, and channels. Two view drawings of bulkheads, bracket plates, hatches, manhole doors, (watertight and non-watertight) gun ports, hammock berthing, etc.

Three months: Drawing of blower foundations, scuttle butt brackets, tank foundations, knee beam connections at decks and floors; hatches and door combings, ammunition stowage, sanitary partitions, companionways, access trunks, etc.

Second Year

One month: Drawing of simple parts of machines, such as pulleys, levers, spindles, gears, cutting heads of planing and scarfing machines. This will give considerable practice in the use of drawing instruments.

Three months: Practice in reading blue-prints: distance between centers of rivets, interpretation of riveting tables, the drawing of floors, intercostals and lines on shell slope of keel, drawings of keels (vertical, bilge and docking).

One month: Drawing of steel forms of shear blades and parts of joggling machines (two views).

Three months: Instruction in the location of parts on plans used in connection with the drawings of combings, stowage; applied geometrical construction — erecting perpendiculars, parallels; reproducing angles and division of pitch circles. Practice in the location of the sea openings of a ship — hatches, gratings, port holes, shell hoists, etc.

One month: Practice in drawing assembled frames, engine foundation, and double bottom sections.

Three months: Practice in drawing assembled parts of a ship: frames, lattice work for torpedo bulkheads, cage masts, etc. Location of longitudinals and lines of shell and decks from offsets. Practice in picking bars from book tables. Begin the study of the simple shapes of the expansion on irregular surfaces.

Third Year

Six months: Drawing of the bridge ammunition hoist, armored uptakes and views on turrets; work on compartment rearrangements. Locating deck scuppers, boat stowage supports, etc. Considerable practice should be given in "inking in." All drawings made in the third or last year should be inked, traced, and a blue-print made of at least one to illustrate the principle of blue-printing.

Five months: Practice in making drawings from data or sketch of parts made in the shop. The apprentice should also be taught how to mark the drawings so as to show installation of parts. Transverse and longitudinal drawings from offsets of inner and outer bottoms, bulkheads, location of doors, trunks, etc.; through plating and bulkheads, gun port shutters, ship ladders, floors and deck frames, splinter bulkheads; foundations, tanks, boilers, engines, pumps, gun and turret, etc. Drawing of the intersection of objects by planes at angles, as for example, chain pipe on deck, shell hoist through turret levels, etc. Drawings involving triangulation to lead up to the drawing of developed shell plating.

One month: A cross-section drawing through a given frame: a longitudinal section drawing of a ship. This is given to test the apprentice's knowledge of the ship and the use of related plans.

QUESTIONS FOR DISCUSSION

1. Explain why a group of apprentices appear more interested in a poorly prepared trade drawing lesson, simply copying, than in an effectively prepared lesson in shop English.

2. Is mechanical drawing fundamental to all trades?
3. Explain the difference between the drawing a draftsman performs and the drawing a mechanic needs.
4. If you were teaching drawing to a group of mechanics, would you begin by teaching the constructional problems in geometry?
5. What should a boy between the ages of fourteen and sixteen, in an industrial school, know about a drawing?
6. How would you present the first lesson in shop sketching to a group of machinist apprentices?
7. How would you present a lesson in blue-print reading to a group of shipfitters in an evening school?
8. Is it a good plan to insist in the beginning on finished drawings, in an industrial school? Why?
9. Is it possible for the average industrial school pupil to concentrate his attention on technique of drawing, and the principles of drawing involved, at the same time? Why?

LIST OF REFERENCE MATERIAL FOR FUTURE READING

Value of Art in the Industrial School. W. Largen. National Educational Association Proceedings, 1912.

(Shows the need of art in all phases of industrial education.)

* *Shop Sketching.* Frank E. Mathewson.

(A discussion of the subject of shop sketching and the method of teaching it.)

** *Problems in Mechanical Drawing.* Charles A. Bennett.

(Collection of plates from which suitable material may be selected.)

CHAPTER XIII

METHODS OF TEACHING SHOP SCIENCE

COURSES in science were introduced into the secondary schools of this country about a generation ago, on the ground that a training in science was a desirable part of a high-school education. The advocates stated that science was the foundation stone of modern industrial development, and that every pupil with a high-school education should have an interest in scientific discovery in order to improve and enlarge the methods of scientific reasoning.

The course of science in a high school consists of biology, botany, geology or physical geography, physics and chemistry. The subjects are presented to high-school students along the lines the teachers were taught at college, in order to develop the scientific attitude of mind. The work consists of textbook and laboratory practice of a very formal character; that is, exercises to study the laws of science for their own sake. The teacher assumes that if the pupil knows the principles of science, he will be able to discover these principles in operation in the ordinary affairs of life and shop or industrial processes.

Experience has shown us that this assumption is not true for the average pupil. To illustrate: after the average boy has completed a course in physics in the high school, he will go out into the industrial world and pass over many practical applications in which the principles of physics that he has studied would apply; he fails utterly to recognise in these situations the physical laws he knows only in an abstract way.

A large number of colleges and scientific schools have corrected this false notion by establishing two departments of science, pure science and applied science. The department of pure science trains the student to study the laws of nature and see exactly what they are, regardless of the practical use of them. The theory underlying such a course is that the student can accomplish the best results when he concentrates his attention on the laws of nature without the application. Such a training develops the research scientist, who, in order to work efficiently, must concentrate his attention on a few facts at a time. The course in applied science is to train a student in the application of principles of science to industrial operations. The course in pure science has failed to do this because it has neglected to lay emphasis on the mental activity which we call "application." Psychologists have shown that application is a most difficult mental process, and needs to be learned just as the original principle is learned.

While the progressive colleges have differentiated between pure and applied science courses, the secondary and intermediate schools have failed to do so. Various attempts have been made to meet this deficiency, in part by the introduction of first-year general science in high schools; but even this course has not been sufficiently developed to say it is a success. The principal reason why applied science teaching has not been more effective is due to the false theory that the average student of high-school age can acquire the scientific attitude of mind, and that the high school should prepare for college. While the author believes there is a place for the traditional courses in biology, chemistry, physics, etc., for the boy between the ages of fourteen and eighteen, he is also convinced of the absolute necessity of an entirely different course in the application of principles of science to shop and industrial practices for the majority of boys who are destined to enter industries. Such a course in science will develop a type of mental attitude which will be valuable to the industries of this country. This course in shop or industrial science will differ considerably from the applied science course in the college, as the types of mind differ, although it will bear somewhat the same relation to the regular science course as the applied science [1] bears to the pure science in the college.

The industrial workers and tradesmen are recruited from the ranks of the motor-minded children with strong physique, who are mechanically inclined. The type of mind represented by these children is not able to grasp and understand abstract scientific principles efficiently, or to the extent of the abstract-minded child, who has the power to grasp and understand abstract principles without a background of experience or observation. The mechanically inclined boy has a tendency to personify all chemical and physical changes. He is able to reason one step at a time only, and usually draws on his imagination in explaining the cause of an effect. The habit of personifying action is very common among all mechanics, who explain the effervescence of acid and a metal as "boiling," corrosion as "eating," etc. There is another great distinction between the practical mechanic and the man of scientific mind. The practical mechanic has the strong force of competition acting on him, and he develops the habit of performing practical tests, "short cuts," or quick methods; that is, he will cast aside a method if it does not "work," without studying the reasons or analysing the situation. The man of scientific mind, on the other hand, will spend considerable time, without regard to expense, in order to test the coherency of the reasoning.

Therefore a course in shop science should be adapted to the type of mind of the boy who is about to enter industry as a worker and to the needs of the different trades. The course should consist of the principles of science underlying the raw materials, tools, appliances, processes, hygiene, etc., of a trade.

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[1] See *Applied Science for Metal-Workers*, and *Applied Science for Wood-Workers*, by W. H. Dooley.

The method of teaching will consist of studying the principles involved in the manufacture of raw materials, action of tools and other appliances, the principles involved in the processes, etc., with not so much emphasis on the shop operations. By discovering the common principles in a great variety of shop situations in a trade, a type of mental attitude is developed which is very different from that which is cultivated in merely contemplating a single fact, as in the case of pure science. The motor type of mind will find in the above course of shop science an opportunity for continuous mental enjoyment and the development of industrial intelligence. The method of teaching shop science is to be inductive or the natural method, rather than the deductive or regular school method. A suggestive plan for a three-year apprentice course is as follows:

Discuss objectively the materials, tools, etc., with the tool or picture or diagram before the class.

Then have the class write the description with sketches in a book. Most pupils lack the ability and knowledge of English to write a description after the teacher's talk. Therefore it is better for the teacher to write the description on the board, and have the pupils copy it. This plan will develop a technical vocabulary. Teachers should correct the books at least once a month.

The work in science should be covered in three years as follows:

I. First year:
  a. Properties and uses of materials, etc.
  b. Description and manufacture of hand tools.
  c. General notion of transmission of power.

d. General notion of power tools and appliances.
e. Simple rules for safety.

II. Second year:
  a. More detailed description of the manufacture of materials used.
  b. More detailed description of the parts, uses and manufacture of power tools.
  c. More detailed description of safety devices.
  d. More detailed description of transmission of power.

III. Third year:
  a. Review of principles of sciences underlying trade as previously described in an unorganized manner.
  b. Study of the principles of testing apparatus.
  c. Study of the strength of materials.

To illustrate: the shop electrician should receive a training in the principles of science underlying the manufacture and the operation of the following tools:

Electrical Department: Machines, Tools, and Materials, used in the Trade

Machines	*Materials*
Lathes, large and small	Sheet brass — $\frac{1}{16}$ to $\frac{1}{4}$ in thickness
Drill presses, large and small	Sheet copper $\frac{1}{16}$ to $\frac{1}{4}$ in thickness
Shaper	Sheet iron $\frac{1}{16}$ to $\frac{1}{4}$ in thickness
Milling machine	Rod brass
Punch press	Rod copper
Motors (shunt)	Rod iron
	Copper wire of various sizes and with different types of insulation
Motors (series)	
Motors (compound)	
Generators (G.E. type)	
Pipe bending machines	
All types of storage batteries	

DIRECTOR OF INDUSTRIES Bengal.

Hand Tools for Electricians

Torch, gasoline
Wrench, Stillson, 6″
Wrench, Stillson, 8″
Wrench, monkey, 6″
Wrench, monkey, 12″
Brace racket, 12″ sweep
Bit (wood), ¼″
Bit (wood), ⅜″
Bit (wood), ½″
Bit (wood), ⅝″
Bit (wood), ¾″
Bit (wood), 1″
Screw drivers, standard, 6″
Screw drivers, standard, 8″
Screw drivers, standard, 12″
Pair pliers, long nose, 6″
Pair pliers, side cutting, 8″
Pair pliers, diamond cutting, 6″
Chisel, wood, 1¼″ socket firmer
Chisel, cold, ½″ × 6″
Chisel, cold, ¾″ × 8″
Pair pliers, gas, 10″
Gauge, ¾″
Pair scissors (elect), 5″
Center punch

Nail set
Hammer, ball peen, 16 oz.
Hammer, claw, 20 oz.
Drill, small hand, with bit
Hack saw frame
Hack saw, 14″ frame
Bit, wood expansion, ⅞″ to 1½″
Reamer burring, ¼″ to 1¼″
Saw compass, 12″
Copper soldering, 3 oz.
Drill-bit, wood bell-hangers, ¼″ × 12″
Drill, ⅜″ × 24″
Pair calipers, inside joint 6″
Pair calipers, outside joint 6″ firm
Pair dividers, 6″ spring
Ruler, 6 ft. folding (wood)
Ruler, 2 ft. folding (wood)
Square combination, 12″ protractor with head
Pair pliers, round nose, 6″
Breast drill
Torch, alcohol
Gauge wire — B × S
Gauge wire, micrometer
Hammer (tack)
Tape measure liner, 50 ft.

Transmission of Power

A. Power and its application in the Shops.
  a. Sources of power as applied to machines.
  b. Transmission of power from sources to various shops.
  c. Pulleys.
  d. Belting and shafting.
  e. Electric drive.
  f. Gears and gearing.
  g. Rim velocity.
  h. Cutting-speed.

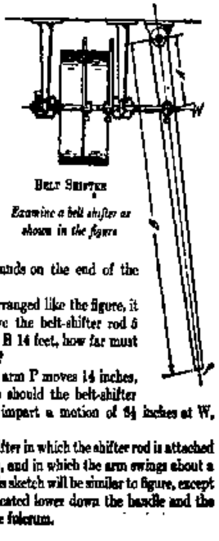
Problems on the principles of science should be expressed in terms of actual parts of a machine that the student or apprentice has worked on in the shop. For example, the belt shifter of an engine lathe would illustrate the principles of levers.

Specimen Lesson Sheet in Science for Machinists, illustrating the Law of the Lever

(1) The resistance of the belt on line W is 80 pounds. If dimension A is 24 inches and B 16 feet, how many pounds must a machinist apply on the end of the arm at P in order to shift the belt?

(2) If the resistance of a belt is 45 pounds, the shifter arm 20 feet long, and the shifter rod fastened 8 feet from the upper end of the handle, how much pull must be given the end of the arm?

(3) If dimension A is 18 inches and B 12 feet, how many pounds can a man exert on the belt-shifter rod at W if he pulls 60 pounds on the end of the arm P?



BELT SHIFTER

Examine a belt shifter as shown in the figure

(4) If on a belt shifter arranged like the figure, it becomes necessary to move the belt-shifter rod 5 inches, and A is 2 feet and B 14 feet, how far must the end of the arm P move?

(5) When the end of the arm P moves 14 inches, how far from the fulcrum should the belt-shifter rod be located in order to impart a motion of 2½ inches at W, dimension B being 20 feet?

(6) Make a sketch of a shifter in which the shifter rod is attached to the upper end of the arm, and in which the arm swings about a point nearer its center. This sketch will be similar to figure, except that the fulcrum will be located lower down the handle and the shifter rod will be above the fulcrum.

(7) Suppose that in a shifter arranged like your sketch, the belt is to move 4 inches, and the distance from the upper end of the lever to the bolt about which it swings is 18 inches. How far is it from the fulcrum bolt to the lower end of the handle, if the end of the handle is restricted to a movement of 18 inches?

(8) In a shifter as shown by your sketch, does the handle have to be moved in the same or in the opposite direction from that in which the belt is to move?

(9) If in problem 8, a force of 80 pounds is necessary at the shifter in order to move the belt, what force must the machinist use on the lower end of the handle?

The meaning of "horse-power," "kilowatt," "mechanical efficiency," and other mechanical terms of common use should be made clear to all.

Miscellaneous Tools used in Steam Plant

Riveting hammers
Electrical pyrometer for annealing furnaces
Cranes overhead — traveling
Elevators, hydraulic
Annealing furnace
Heating systems
Dynamos
Air compressors
Boilers and stokers
Pumps
Condensers
Coal-handling equipment
Ash-handling plant
Feed water heaters
Sun printing frame
Calculating machine
Adding machine
Blue-print machine

Instrument Room, Testing Supplies, etc.

Oil-testing outfit
Gauge test pump
Vacuum pump and mercurial scales
Sensitive balance and cabinet
Angle viscometer
Oil-hydrometer set
Specific gravity hydrometer set
Traction dynamometer
Hydraulic gauge tester
Tensile testing machine
Oil-testing friction

Measuring Instruments in use in the Shops

1. The watch
2. The yard stick — 2 foot rule, steel tape
3. Calipers (ordinary and micrometer)

4. Protractors
5. Scales
6. Thermometers
7. Gas meters
8. Water meters
9. Electric meters
10. Machines for testing materials

Specific gravity should receive considerable attention; so should the mechanism, of the more common types of meters. Practice in reading micrometers, calipers, and gas, water, and electric meters.

Safety in industry

(1) Necessity for guarding against industrial accidents.
(2) Safety devices and their uses.
(3) The human element in accidents.
    (*a*) Ignorance of danger.
    (*b*) A preoccupied mind.
    (*c*) Thoughtlessness.
    (*d*) Carelessness.
    (*e*) Recklessness.
    (*f*) Showing off.
    (*g*) Lowered vitality, as in sickness.
    (*h*) Excitement.
    (*i*) Fooling and playing pranks.

1. *The safety movement.*

   A statement of the industrial accident problem giving statistics of accidents in the United States as a whole, for groups of industries and in particular plants. Include, if possible, statistics of accidents in shop, with specific classification. Indicate from data that the majority of accidents are not due to machinery, or lack of safeguards, but rather to carelessness, or indifference on the part of the workmen. Use of slides.

2. *How plants have organized for safety.*

   Give typical organizations for safety in industrial plants and cite the reduction in accidents resulting through their operation. Cover the proposed organization for the shop. The duties of Workmen's Committees should be covered in detail.

3. *Safe and unsafe practices.*

   Select from the files of the medical department, cases of accidents resulting clearly from carelessness on the part of the workmen. Unsafe practices. Indicate how the accident might have been avoided.

4. *Good housekeeping and the tripping hazard.*

   Indicate the relation of good housekeeping to the accident hazard, i.e., keeping the shop well cleaned up and orderly arranged, safe piling of material, racks and receptacles for tools, stock, etc., the tripping hazard, clear aisles and passageways, etc.

5. *The construction of safeguards.*

   Exhibit the racks showing construction of common guards for belts, gears, etc. Use slides of typical installations, indicating the materials used, etc., etc.

6. *Stairways, floor openings, platforms, scaffolds and ladders.*

   Standard hand rails for stairs, floor openings, etc.; proper angle for stairs, ladders, etc.; slides of unsafe ladders found in use; standards for construction of scaffolds.

7. *Power transmission equipment.*

   Indicate in detail the standard requirements for guarding all main shafting, jack shafting and counter shafting. Guards for vertical and horizontal belts, shafting, etc.; safety couplings, collars and set screws; remote controls.

8. *Wood-working safeguards.*

   Slides on guards for circular, swing and band saws; jointers; planers; shapers. Emphasize the need for using such guards as are provided.

9. *Machine-shop hazards.*

   Slides on guards for drill presses, lathes, punch presses, boring mills, etc.

10. *Safety in foundries.*

    Slides on safe foundry ladles, guards for sand mixers, tumblers; foundrymen's shoes, leggings, goggles, hand leathers, etc.

11. *Crane practice.*

    Walks, railing and platforms; trolley guards, safety limit stops, limit switches, etc.

12. *Grinding-wheel safeguards.*

    Slides on proper mounting of wheels; adjustment of rest; design of guard for wheel; eye shield, etc.

13. *Eye protection.*

Slides and exhibit of goggles for chippers and grinders and colored glasses for electric welders, etc. Indicate the dangers of picking things out of each other's eyes; show the reduction in eye injuries where men have used goggles.

14. *Electrical hazards.*

Is low-tension apparatus dangerous? Slides on safety switches, use of rubber gloves, sleeves, etc.

15. *First aid to the injured.*

Demonstrate the prone pressure method of artificial respiration for electric shock, drowning, etc. Have members of class try it on each other. If possible, have physician from medical department present.

QUESTIONS FOR DISCUSSION

1. Pattern-makers frequently determine the weight of a casting from a pattern. This depends upon the principle of specific gravity. When would you teach the pattern-maker the theory of specific gravity? Why?
2. Explain why an apprentice steam engineer would in the beginning rather wheel coal than calculate the B.T.U. power of the coal.
3. When should a plumbing apprentice receive the chemical composition of "raw acid," "killed acid"?
4. When should wood-workers receive the knowledge of the growth of trees so as to be able to tell the defects in the wood?
5 When would you teach the machinist the theory of the micrometer?
6. An instructor who was explaining the use of a speedometer for the first time also included a detailed description of the construction of the instrument. Was this good teaching in an industrial school?
7. If you were an instructor of applied physics in an industrial school and desired to teach the subject of levers to a group of machinists, how would you start? Why?
8. During the first few months of a course in shop science, would you place more emphasis on the recent experiences of the pupil or the subject in the book or laboratory? Why?
9. What is the principle of science involved in getting horse-power of a given engine from an indicator card?
10. How would you present the subject of horse-power to a group of firemen in an evening trade class?
11. What principle of science is involved in teaching the cutting-speed for different metals?
12. Give the outline of a lesson showing how you would present to a class of pattern-makers in an evening school the subject of getting weights of casting from pattern by table of trade numbers?

13. Should a pupil in a plumbing department wipe joints or learn the composition of solder first? Why?
14. Ask a number of mechanics, what they first acquired, the practice or the theory.
15. Explain why it is not difficult to hold the attention of all boys for at least a while on a working model of an automobile.
16. Explain why most mechanics find it difficult to discuss problems in mechanics in the abstract.
17. What objection is there to a teacher of related trade knowledge teaching shop practice?
18. Why is it difficult for the teacher to receive real concentration on the theoretical principles of the mechanics of a tool from the average industrial school pupil?

LIST OF REFERENCE MATERIAL FOR FUTURE READING

* *Applied Science.* A. H. Morrison, National Education Association. Proceedings, 1914

(Emphasizes the importance of the applications of the principles of science.)

** *Industrial Hygiene and Vocational Education.* National Education Association. Proceedings, 1914.

** *The Natural Sciences.* George R. Twiss. *Principles of Secondary Education.* Edited by Paul Monroe.

(The aim and value of the natural sciences.)

* *The Teaching of Physics.* C. R. Mann.

(Methods of teaching science in secondary schools.)

Science Teaching as seen from the Outside. E. L. Thorndike. Bulletin 34. New York State Department of Education.

(Need of more practical science teaching.)

* *How It Works.* Archibald Williams.

(A description of the industrial application of steam, electricity, optics, hydraulics, light, etc., in very simple language.)

** *The Romance of Modern Manufacture.* Charles R. Gibson.

(A popular account of various mechanical and chemical industries.)

CHAPTER XIV

INDUSTRIAL OR SHOP MATHEMATICS

One of the most difficult subjects to teach effectively to boys is vocational mathematics. This may be due to the fact that many principles of mathematics are very abstract, and have never come within the experience or observation of the child. The laws of mental development state that a child must be led gradually into an abstract subject. Therefore the principles of mathematics should be vitally and persistently connected with the pupil's experience in a shop. When this idea is instilled into the mind of the pupil, he will go about his work with greater interest and less coaxing.

The first part of each lesson should be devoted to a discussion of the part of the trade that requires the principle of mathematics. This offers an incentive for the pupil to study the subject. As far as possible have the pupil give practical proofs. For example, in teaching the relation between the diameter of a pulley, and the distance around it, ask the pupil to draw a chalk line on the floor and mark the rim of the pulley with a chalk mark, then roll the pulley along the chalk line until the pulley has made one complete revolution as indicated by the chalk mark on the rim. The diameter of the pulley is obtained by measuring across the pulley. Divide the distance around the pulley by the diameter and show the relation.

In all parts of vocational mathematics emphasis should be laid on the objective teaching. Models should be constructed if necessary. To illustrate; in teaching the relation between the number of teeth and the speeds of gears, a rack may be constructed to hold a number of gears. Begin with two gears, 24 teeth and 48 teeth. Mark a check line on a tooth of the small gear, and notice the number of teeth or part of revolution the large gear turns, while the small one makes one complete revolution. The pupil will see that the small gear makes more revolutions than the large one. When another gear is placed in the rack between them acting as an idler, similar reasoning will show that the middle gear causes the third gear to have the same direction as the first.

THE NECESSITY OF INDIVIDUAL INSTRUCTION IN APPRENTICE AND VOCATIONAL CLASSES

Students in higher vocational classes are obliged to meet certain minimum requirements before they are allowed to pursue a vocational course. As a result it is possible to work with a class as a whole in teaching related trade technical knowledge.

A study of the record cards of the apprentices in the different trades will show that the apprentices vary greatly in their previous educational training: some have been in the country a few years and have a very scant knowledge of the English language; that is, they speak and write English imperfectly. Most of the apprentices come from the sixth and seventh grade, some from the eighth grade, and a few from the high school. It is clear that with such a wide range of grading it is impossible to do much class teaching. Any attempt to grade apprentices into classes according to their educational attainments would interfere with the shop organization and develop administrative difficulties. Therefore the most effective method of teaching is by groups and individuals. Graded lesson sheets must be prepared each day and given to the apprentices according to their ability. The apprentices from the upper grades and the high school will not require as much individual instruction as the apprentices from the lower grades.

One of the most effective methods of carrying on individual work is to have an envelope for each pupil. As fast as he finishes a lesson sheet he should hand it to the teacher for correction. The instructor goes over the sheet in detail with the pupil, explaining the incorrect problems. Corrections may be written on the papers and then filed away if satisfactory to the teacher. In this way the pupils retain their own corrected papers, and can refer to them at any time. Marks may be recorded on the back of the envelope that is used to hold the corrected papers as shown below.

Grade Monthly		Name	Trade	Class
	Subject			
	Effort			
	January			

METHOD OF TEACHING

The most effective system of teaching shop mathematics to apprentices is the individual plan; that is, having a series of sheets each one containing a type of problem used in that trade. The first problem should be solved on the paper in very simple language followed by four or five drill problems. In this way it is possible to give each apprentice graded lessons.

Sample of a graded lesson in board measure for joiners

A **foot** in board measure, or a "board foot," means a piece of lumber having an area of 1 square foot on its flat surface and a thickness of 1 inch or less. The word "foot" is generally used instead of "board foot," as it is shorter. For example: "Four feet of lumber" means four board feet of lumber. Fig. 1 shows a board containing four board feet.

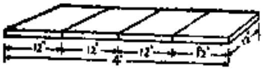


Fig. 1

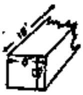


Fig. 2

The rule for finding the number of board feet in a piece of lumber is as follows: **Multiply the number of square feet in its flat surface by the number of inches in thickness, counting any thickness less than 1 inch as an inch.**

Suppose we wish to find the number of board feet in a piece of lumber 1 inch thick, 8 inches wide, and 15 feet long, then we will have:

$$\frac{8 \times 15 \times 1}{12} = 10 \text{ feet.} \quad \textit{Ans.}$$

Lumber. The term "lumber" is generally applied to pieces not more than 4 inches thick.

Timber. The term "timber" is applied to pieces more than 4 inches thick.

Board and Plank. Any piece of lumber under $1\frac{1}{2}$ inches thick is usually called a "board"; and a piece from $1\frac{1}{2}$ inches to 4 inches thick is called a "plank."

Rough Stock. The term "rough stock" means lumber having its dimensions a little larger than is actually required, to allow for planing, truing up, etc.

Dressed. The term "dressed" has much the same meaning as "planed."

Surfaced. The term "surfaced" is usually applied to boards or planks that are planed on one or both sides.

Jointed. The term "jointed" has reference to lumber planed on its edges. It is also used to designate pieces that are made straight on the edges.

Allowance for dressing. If lumber is dressed it loses in size the amount taken off in shavings. Usually for stock 1¼ inches or more in thickness the loss is about ⅛ inch on each surface planed. Hence a piece 8 inches wide and 2 inches thick when rough, becomes 7¾ inches wide and 1¾ inches thick when dressed, if planed on all four surfaces.

In estimating board feet all lumber one inch in thickness or less should be considered 1 inch thick. Rough lumber or timber is estimated in ¼ and ½ inch thickness over the even inch. Examples: 1¼" at 1¼", 2½" at 2½", 2¾" at 3" and 3¾" at 4". Intermediate thicknesses would be estimated at the next larger thickness. For example: 1⅛" would be estimated at 1¼", 1⅜" at 1½", and 1⅝" at 1¾", and 1⅞" at 2. The above rules also apply to all dressed lumber.

Fig. 8 shows the end of a piece of timber which is 6½ inches thick, 8 inches wide, and 18 feet long. How many board feet does it contain? Applying the rule we will have:

$$\frac{8 \times 18 \times 6\frac{1}{2}}{12} = 78 \text{ feet., } \textit{Ans.}$$

Standard lengths of lumber in most sections are 10, 12, 14, 16, 18 feet, etc. If cut to a special length it always costs more.

The following simple table is very useful for calculating board measure (feet long), for lumber 1 inch or less in thickness:

Pieces	8"	wide contain	⅔ as many feet as they are feet long.
"	4"	" "	⅓ " " " " " " " "
"	6"	" "	½ " " " " " " " "
"	9"	" "	¾ " " " " " " " "
"	12"	" "	as many feet as they are feet long.

Examples for Drill

1. How many board feet in a piece of lumber ¾ inch thick, 8 inches wide and 12 feet long?

2. How many feet in a piece of timber 6½ inches thick by 10½ inches wide by 16 feet long?

3. Find the number of board feet in the following 8 pieces.

1" × 3" × 16 ft.	2" × 9" × 16 ft.
¾" × 4" × 12 ft.	6" × 9" × 14 ft.
1¼" × 3" × 16 ft.	7" × 12" × 20 ft.
1½" × 4" × 12 ft.	9" × 12" × 20 ft.

4. How many board feet in 8 pieces of timber each 6" × 6" × 18 feet?
5. Six boards have the following dimensions:

1" × 8" × 10 ft.	1" × 7½" × 16 ft.
1¼" × 6" × 16 ft.	1" × 6¼" × 16 ft.
1" × 8½" × 16 ft.	1¼" × 9" × 16 ft.

   How many board feet are there in the lot? (Add the widths together first, then apply the rule.)
6. How many board feet in a plank 1¼ inches thick, 11½ wide, and 14½ inches long (nearest foot)?
7. How many board feet of stock are required to build a platform 8 feet 6 inches square if the stock is 1½ inches thick and we allow 8 board feet for waste due to squaring up the ends of the boards?

The width of common rough timber or lumber runs in ½ inch sizes; as, 6½, 7, 7½, 8, 8½, 9, etc. For widths running in fractions less than ½ inch use the next highest ½ inch size. For example, a board 6¼ inches wide would be called 6½ inches and one 6¾ inches wide would be called 7 inches wide.

1. A piece of rough stock (" rough stock " means lumber having its dimensions a little larger than is actually required to allow for planing, trueing up, etc.) is ⅞ inch thick, 9 inch wide, and 16 feet long. How many board feet does it contain?
2. How many board feet in a piece of rough stock 18 feet long, 7¾ inches wide, and 1¼ inches thick?
3. A piece of lumber is 10 inches wide at one end and 12 inches at the other and is 1¼ inches thick and 13½ feet long. How many board feet does it contain?

Lesson Sheet on Mathematics for House Carpenter

Fig. 1 shows a piece of matched flooring. When estimating flooring, ceiling, sheathing, or other lumber that is matched (that is, having a tongue and groove joint as shown in the figure) enough stock must be added to make up for the amount cut away from the width in matching. This amount varies from ¼ inch to ¾ inch on each board according to its size. A little flooring is always wasted in squaring the ends, cutting up, etc., and to offset this a few feet are usually added to the total estimate. For flooring, sheathing, etc., from about 2¼ inches to 5¼ inches in width, the amount allowed or added for matching is generally one fourth. For example, if a common floor to be laid with matched boards is 12 feet square, the amount of flooring required is 144 feet plus ¼ of 144 or 36 feet making in all 180 feet. If the floor to be laid is of pieces 1½ inches wide, the amount usually allowed for matching is one third or in the above case we would add ⅓ of 144, or 48 feet.

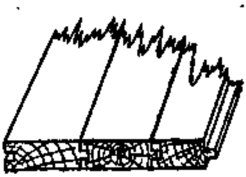


Fig. 1

1. Estimate how much ⅞-inch matched flooring 3 inches wide will be required to lay a floor 16 feet by 18 feet. Allow one fourth more for matching and add 9 per cent for squaring the ends. Get answer to nearest foot.
2. How much hard-pine matched flooring ¾ inch thick and 1½ inches wide will be required for a floor 13 feet 6 inches by 14 feet 10 inches. Allow for matching and add 4 per cent for waste. Get answer to nearest foot.
3. An office floor is 10 feet 6 inches wide at one end, 9 feet 6½ inches wide at the other, and 11 feet 7 inches long. If it is laid with hard-maple matched flooring 1 inch thick and 1½ inches wide, what will the lumber cost at $60.00 per M? Add 4 square feet for waste.

Specimen Lesson Sheets: Gearing

Go to the shop and select two 48-tooth gears. Clamp them in the gear rack so that they will work together as shown in Fig. 1. Make a chalk mark on the tooth of each gear which just shows above the top of the rack. Turn the gear *A* one turn in a direction the same as the hands of a clock until the chalk mark comes back to the starting point.

1. How many teeth on gear *B* passed the top of the rack while gear *A* turned once? *Ans.*
2. How many turns or parts of turns did gear *B* make when gear *A* turned around once? *Ans.*
3. When you turned gear *A* in the direction of the hands of a clock did gear *B* turn in the same or opposite direction? *Ans.*

When a gear turns in the same direction as the hands of a clock it is said to turn right-handed. When a gear turns in the opposite direction to the hands of a clock it is said to turn left-handed.

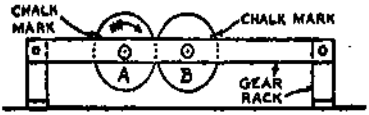


Fig. 1

When two gears run together the one that is nearest the source of power is called the driver and the other gear is called the follower. In some trains of gears used in lathes we have several drivers and several followers.

Lesson Sheet in Shop Mathematics: Gearing[1]

Place a 96- and 48-tooth gear in the rack so that they will run together as shown in Fig. 1. Make a chalk mark on the 96-tooth

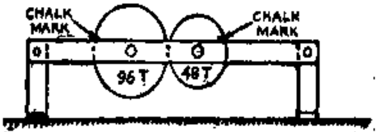


Fig. 1

gear at the top line of the rack and a similar mark on the 48-tooth gear. Turn the 48-tooth gear one turn right-handed.

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[1] For more detailed problems see *Vocational Mathematics*, by W. H. Dooley.

1. How many teeth passed the top of the rack on the 96-tooth gear? *Ans.*
2. How many turns or parts of turns did the 96-tooth gear make? *Ans.*
3. In what direction did the 96-tooth gear turn? *Ans.*
4. What is the ratio of the gearing in this case? *Ans.*
5. What would be the ratio of the gearing if we took out the 48-tooth gear and put in a 32-tooth gear? *Ans.*
6. If we turn the 96-tooth gear 4 times, how many turns will the 32-tooth gear make? *Ans.*
7. How many turns would the 96-tooth gear make if we gave the 32-tooth gear 7½ turns? *Ans.*

Lesson Sheets on Drill Problems on Gearing

1. A 108-tooth gear drives a 28-tooth gear. What is the ratio of the gearing? *Ans.*
2. What would be the ratio of the gearing if the 28-tooth gear was the driver? *Ans.*
3. If the 28-tooth gear is making 48 r.p.m., how many r.p.m. is the 108-tooth gear making? (See *Note* below.) *Ans.*
4. How would we change the gearing to make the 28-tooth gear turn in the same direction as the 108-tooth gear? *Ans.*
5. Two gears running together have a speed ratio of 7 to 1. If the smaller turns 14 times, how many times will the larger turn? *Ans.*
6. In the last problem how do you know that the answer is 14 ÷ 7 instead of 14 × 7? *Ans.*
7. A 144-tooth gear makes one complete turn. How many turns will a 32-tooth gear make working with it? *Ans.*
8. If in the last problem the 32-tooth gear turned once, how many turns will the 144-tooth gear make? *Ans.*

Note: The letters "r.p.m." mean "revolutions per minute." This abbreviation will be used hereafter in the course.

Lesson Sheet in Shop Mathematics

Suppose we have two shafts, *A* and *B*, as shown in Fig. 1, and that we want to connect these shafts by gears so that the shaft *A* will make one revolution while the shaft *B* makes two. In order to do this we must place a gear on shaft *A* having two times the number of teeth as the gear on shaft *B*. If we put a gear on *A* having

96 teeth, the gear on *B* will then have 48 teeth, or just one half as many, and each time the gear on *A* turns around once the gear on *B* will turn twice; that is, the 96 teeth on gear *A* will have to turn gear *B* twice in order to mesh with 96 teeth on *B*.

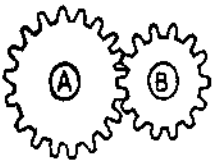


Fig. 1

The relation or ratio of the speed of *B* to the speed of *A* is 2 to 1. This is called the ratio of the gearing. We can now write the ratios between the speeds and the number of teeth in the form of a proportion, thus:

96 : 48 : : 2 : 1

or in words, the number of teeth on gear *A* is to the number of teeth on gear *B* as the speed of *B* is to the speed of *A*.

1. A 48-tooth gear drives a 120-tooth gear. What is the ratio of their speeds? *Ans.*
2. Two shafts are connected by gears, one turns 55 times a minute and the other makes 11 turns a minute. If the smaller gear has 32 teeth how many teeth has the larger gear? *Ans.*

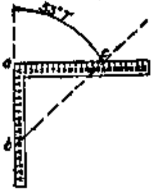
Lesson Sheet on Angular Measurements

One of the most difficult subjects to teach a practical mechanic is the relation of the chord and the angle. This subject may be presented in a very practical way as follows:

1. Lay off the following angle with a two-foot rule by measuring the chord:

Sketch	Angle in degrees	Chord in inches	Angle in degrees	Chord in inches
	5	$\frac{17}{32}$	50	$5\frac{1}{16}$
	10	$1\frac{3}{64}$	55	$5\frac{17}{32}$
	15	$1\frac{9}{16}$	60	6
	20	$2\frac{5}{64}$	65	$6\frac{7}{16}$
	25	$2\frac{19}{32}$	70	$6\frac{7}{8}$
	30	$3\frac{7}{64}$	75	$7\frac{5}{16}$
	35	$3\frac{19}{32}$	80	$7\frac{23}{32}$
	40	$4\frac{7}{64}$	85	$8\frac{7}{64}$
	45	$4\frac{19}{32}$	90	$8\frac{1}{2}$

9. Lay off the following angles with a steel square:

Sketch	Angle in degrees	Distance in inches	Angle in degrees	Distance in inches
	5	$1\frac{1}{16}$	33° 42'	8
	10	$2\frac{7}{64}$	(⅓ Pitch)	..
	15	$3\frac{7}{32}$	35	$8\frac{13}{32}$
	18° 25'	4	40	$10\frac{1}{16}$
	(⅙ Pitch-roof)	..	45	12
	20	$4\frac{3}{8}$	(½ Pitch)	..
	22½	$4\frac{31}{32}$	50	$14\frac{5}{16}$
	25	$5\frac{19}{32}$	53° 7'	10
	26° 33'	6	(⅔ Pitch)	..
Lay off — ab = 12" Lay off — ac = distance	(¼ Pitch)	.	55	17⅛
	30	$6\frac{15}{16}$	60	$20\frac{25}{32}$

Lesson Sheet on Cost

In connection with mathematics, it is possible to teach the meaning of a great many industrial terms, such as "day rate," "premium rate," "earned rate," "overtime rate," etc. These terms may be aroused by such questions as:

What is meant by hourly or day rate?

What is meant by earned rate?

When are you paid overtime?

Do you get premium when working overtime?

How does coming in late in the morning affect your overtime?

Does the company pay overtime for work done during the noon hour?

Does overtime increase the cost of a job?

Of what advantage is overtime to the company?

What is piece work?

What is meant by paid on account?

What do you mean by time and one-half?

What is a time slip?

What information should a workman put on his time slip, before turning slip in to the time clerk?

What is done with the time slip after the workman turns it in?

Sample of a Cost Sheet

Name.................................... **Grade**.................... **Class**....................
Trade.................... **Class**.......... **Date**....................

SHOP MATHEMATICS

ESTIMATE OF COST OF MANUFACTURING................

PIECE NUMBER ....

Cost of Labor

Operation Number	Operation Description	Machine Used	Number of Pieces	Hours Mechanic	Hours Helper	Rate Mechanic	Rate Helper	Cost of Labor	Total Cost of Pieces	Cost of One Piece
Totals										

Materials

Description	Number	Length	Width	Thickness	Weight	Unit Cost	Total Cost	Cost per Piece
Totals								

Overhead Charges

....

....

Grand Totals....................

What is done with the time slip after the pay roll is made up?

Is the time slip ever destroyed?

Is there harm in putting more time on the time slip than the actual hours worked on the job?

What effect will this have on the cost of the job?

What are the things that enter into the cost of a job?

A cost sheet should be given to the pupil, and practice given in working out costs. The overhead charge may be considered as a certain per cent of the labor, as 30 per cent for sheet-metal trades.

Related Trade Knowledge of a Scale

Give each student or apprentice a scale, and ask him to examine it very carefully. Then lead the pupil by asking the following simple one-step questions:

What markings do you find on the scale?

Into how many parts is the inch divided on your scale?

What is the smallest division of an inch that you have seen on any scale?

How many of these divisions does it take to make an inch?

How many quarter inches in one inch?

Write a quarter of an inch fractionally.

Write a quarter of an inch, using decimals.

How many quarters in two inches?

Draw four lines with the scale.

Divide the first line into inches.

Divide the second line into one half inches.

Divide the third line into one fourth inches.

Divide the fourth line into one eighth inches.

Write in decimals $\frac{1}{2}''$, $\frac{1}{4}''$, $\frac{1}{8}''$, $\frac{1}{64}''$, $\frac{1}{32}''$, $\frac{3}{4}''$, $\frac{3}{16}''$, $\frac{3}{32}''$, $\frac{5}{16}''$.

QUESTIONS FOR DISCUSSION

1. Is the study of mathematics industrially fundamental to all trades?
2. Explain why the average teacher in the college section in mathematics is able to hold interest better than the same teacher in an industrial school.
3. Explain why a group of machinists are anxious to know how to change a common fraction to a decimal fraction.
4. Why will an apprentice machinist, who is anxious (ambitious) to become a foreman, acquire shop mathematics faster than a skilled mechanic, who is satisfied with his present rating?

5. A boy enters a trade school from the grammar school. He has left school because he cannot understand fractions. How would you undertake to teach him fractions?
6. A grammar school teacher asked every pupil who failed in a single example in fractions to do ten additional ones. Would this be a good practice in an industrial school? Why?
7. Give five practical mathematical problems in the following trades: Machinist, plumbing, steam engineering, electrical trades, pattern making, and sheet metal work.
8. A boiler-maker determines the inside circumference of a boiler by multiplying the inside diameter by 3 and allowing one additional inch in every seven inches in the diameter. Why is this method more simple than multiplying the diameter by 3 1/7?
9. An instructor in shop mathematics asked an apprentice to multiply 6¼ by 16½ by 3. The pupil in the pattern making shop took very little interest in this problem. Could the interest be aroused by making the problem concrete?
10. When would you teach the slide rule to an electrical apprentice?
11. How would you teach trigonometry to a group of mechanics in an evening class?
12. If you were teaching a group of motor-minded boys, 14 to 16 years of age, how would you make your instruction concrete?
13. Give the principles of mathematics involved in teaching how to figure gears on a screw cutting lathe.
14. What principle of mathematics is involved in teaching how to obtain an offset for taper turning?
15. How would you explain the principle of shrink rule to a group of pattern making apprentices?
16. Give the outline of a lesson in teaching the principle involved in locating six equidistant holes on a circle, to a group of pupils in a machine shop course in a day industrial school.
17. Give the outline of a lesson for teaching the principle of cutting rafter angles by use of a square to a group of house carpenters in an evening school.
18. Give the outline of a lesson for teaching the slide rule to a group of draftsmen in an evening class.
19. How would you explain the use of logarithms to a class of advanced pupils in a machinist's course in a day industrial school?
20. Give a lesson plan showing how to present the use of a formula to a group of young electrical apprentices.
21. Pupils in an all day industrial school are often obliged to keep a time card, calculate the cost of material and labor, and the price that should be charged for output. What principles of mathematics may be taught in this way?

LIST OF REFERENCE MATERIAL FOR FUTURE READING

* *The Teaching of Elementary Mathematics.* D. E. Smith.
(Methods of teaching elementary mathematics. One of the best books.)

** *A Short Account of the History of Mathematics.* M. R. Ball.
(A concise account of the development of mathematics.)

* "Practical Mathematics." W. H. Dooley. *Mathematics Teacher,* June, 1918.
(A discussion of some of the best methods used in trade classes.)

** *An Elementary Treatise on Graphs.* George A. Gibson.
(Presents the subject in a connected form simple enough in the early stages for the beginner.)

CHAPTER XV

METHODS OF TEACHING ENGLISH[1]

EVERY one has two duties to perform outside of his work — the duties he owes to society: one is to act as head of a family, and the other is to perform the duties of citizenship. As head of a family he should have a training that will give him the intelligence to be a good provider and to know how to enjoy the companionship of his family and his friends, and also to secure honest enjoyment out of life.

Every person in this country has more or less to do with the government. This is the only country in the world that has given to every male citizen of ordinary intelligence the right to vote and to decide how our government shall be conducted. Therefore it is important that general intelligence of the working classes should remain fairly high. In order to have this general intelligence, it is necessary to continue general education in English, civics, and social sciences until the pupil reaches the threshold of manhood. This will conserve what he already knows and will increase his general knowledge.

English is the most important academic subject in the course of study in the day industrial school. Every one must be able to speak and write about the things he is doing, and to be able to make his desires and appreciations known. The teacher should begin by showing the value of English. The necessary English includes ordinary letter-writing, penmanship, spelling of common words, and oral English about his work and every-day life. The desirable English — how to write — includes reports of work done in the school shops, condition of worker and work, the human phase of various occupations, enlarged vocational vocabulary, that one may read technical and trade literature. Cultural English develops a love of reading, an appreciation of good books, reporting, descriptions, etc. The intellectual and emotional side of the student is brought out; also any literary ability.

An effective course in English in an industrial school should tend to develop the following:

1. Ability to express easily and freely oral and written English.
2. A knowledge of the structure and form of the language.
3. A real desire to read.
4. An appreciation of good literature.
5. A knowledge of the best authors.

In teaching English, begin with reports of the shop-work, followed by correspondence, ordering supplies, and then specifications of the projects that the pupils are working on. Then show the need of being able to write about the condition of the workers, followed by a study of good books.

In order to develop a special fondness for books, we must show the pupil an incentive, that the world depends on books for knowledge and happiness. Assign to the pupils readings in books to bring out the good points, after you have read selections to them.

Lesson Sheet on Spelling

LIST OF MACHINE-SHOP WORDS

Machines

Emery wheels
Emery grinders
Tool grinders
Traveling cranes
Testing plant
Standard plug and ring gauges
Dies and taps machine
Surface plates
Taper reamers

Machines

Valve reseating machine
Screw jacks
Hydraulic jacks
Jib cranes
Blanking dies
Erecting plates and blocks
Jigs
Pneumatic hoists
Electric grinders

Machines

Pneumatic drills
Pneumatic corner drills
Die-sinker mill
Saw blade, grinder
Milling planer
Universal milling machine
Milling machine
Plain milling machine
Vertical milling machine
Reamer and cutter grinder
Turbine blade cutting machine
Saw table
Circular saw
Radial drill press
Drill press
Sensitive drill press
Multiple drill press
Drilling and boring machine
Twist drill grinder
Power punch press
Planer
Crank slotter
Electric hand drills
Torches
Vertical boring mill
Horizontal boring mill
Engine lathe
Fox lathe
Gap lathe
Universal grinder (lathe type)
Speed lathe
Universal tool grinder

Machines

Turret lathe
Triple-headed bolt machine
Double-headed bolt machine
Bolt cutting machine
Fox monitor lathe
Automatic screw machine
Semi-automatic screw machine
Monitor lathe
Cutting-off machine
Screw slotter
Tube cutter
Pipe threading machine
Shaper
Double-headed shaper
Draw shaper
Universal key seater
Surface grinder
Spur gear cutter
Gear and worm wheel cutter
Bevel-gear cutter
Open-side planner
Turret rack cutting
Band saw
Gorton disc grinders
Buffing machine
Power hack saw
Magnetic metal separator
Belt-lacing machine
Hydraulic press
Belt-scraping machine
Arbor press

Hand tools

Peen hammer
Chisels
Calipers
Micrometer
Gauges

Materials

Emery cloth, etc.
Tool steel
Soft steel
Wrought iron
High speed steel

Hand Tools	*Materials*
Scales	Cast-iron
Files	Bronze
Scraper	Babbitt metal
Lead hammer	Lubricating oils
Drills and reamers	Belting (leather)
Surface gauge	Waste (cotton)
Surface plate	
Center punch	
Scribe	

The desirable English should include practice in the use of four or five types of letters: letters to a parent or other relative, letter applying for a position, an order or requisition for supplies, letter to a superior official, letter to a public official, letter to a newspaper official, correspondence between two departments of the same corporation, etc. The pupil should also make a study of the use of short stories, and the technical literature of his trade.

Teachers should have the pupils acquire the "library habit." An effort should be made by the instructor to find the list of technical books on each trade. A list may with profit be placed on a bulletin. Later an interest in general reading may be acquired by the pupil.

A boy is least fitted to choose the books which are desirable for him to read. His interests at various ages decidedly influence his reading. A boy's library should supplement his early life. As the boy grows, his interests change from those of boyhood to those of manhood. That is the reason why travel, adventure, invention, biography, love-stories, and outdoor books appeal to the interests and needs of boys at various ages. They should read carefully and slowly so as to absorb what they read. Story-telling, with suggestions where more can be read, is helpful. Not all magazines are interesting to boys. They are interested in magazines of outdoor life, invention, handicraft, etc. Practical talks appeal to working boys. The talk should be informal, providing definite information, new incentives for effort, and definite character-building. A talk should suggest a subject on which the pupil will do further reading. Many of the pupils in vocational and apprentice classes are foreigners or of foreign descent, and the work must be adapted to their needs.

Rules for oral composition. Insist upon correct expression at all times. The pupil should give complete sentences four or five times in reciting. Frequent oral composition on the work being done should be given by the pupil to the class. He should stand in front of the class, in a free and easy position, and state what he is doing.

Careful enunciation of syllables, particularly the final syllable, should be required.

Do not allow the pupil to use long sentences. Cultivate a habit of using short, concise sentences.

Do not permit the use of slang. Teach the pupils to be accurate in their statements, and try to cultivate the use of discriminating words used in the trades.

As far as possible have all written work preceded by oral drill. To illustrate: if a pupil is asked to write a letter to his brother telling of his work, he should tell the class what he is going to write.

The following rules should be required to develop proper writing habits:

1. Write on only one side of the sheet of paper.
2. Have a balanced margin at the top and bottom, and at the sides of paper, on which compositions are written.
3. All sentences should begin with a capital letter.
4. Sentences should end with a period.
5. Sentences involving a question should end with an interrogation point (?)
6. A liberal space should intervene between consecutive lines and consecutive words.

7. The use of commas in series should be used.
8. The use of long compound and complex sentences should be discouraged.
9. Slang should not be used. Shop or technical expressions should be in quotation marks ("   "), and the meaning in parentheses.

The following detached outline will illustrate the above principles:

THREE-YEAR COURSE IN ENGLISH FOR SHIPFITTERS' APPRENTICES

First Year

Time: One month — one hour a week: Practice in spelling and description of the various tools, appliances, materials, and fittings used in the tool-room.

Four months: Short oral and written composition work based on the work of the apprentices, such as drilling, reaming, chipping, and calking on various parts of the ship (deck platforms, compartments, divisions, etc.). Description of such terms as section, stern, port, starboard, forward, aft, and after ends of the ships: bulkheads, shell waterline, tanks (oil, and fresh water), drainage, etc.; armor plate, cage masts, and turrets. This practice will develop in the pupil the power to express what he is doing in simple and direct English.

Four months: Review principles of grammar relating to the use of nouns and pronouns so that the apprentice will know when and how to use capital letters and simple punctuation. Composition on bulkheads, hatches, doors, etc.

Three months: Practice in giving explanations and directions. Develop the power to express in short, concise sentences such as directions marked on templates. Describe length, breadth, thickness, scroll, curve forms, etc. Composition on trunks, ammunition hoist, bits, etc.

Second Year

One month: Simple description (both oral and written) on drilling, planing, scarfing machines, on searchlight platforms and cage mast.

Three months: Review of the section of grammar relating to subject and predicate to show the pupil that the predicate agrees with the subject. Composition on uptakes, bridges, and conning tower.

One month: Letter writing and shop-order slips. Teach four types of letters: letter to a parent; letter to a friend; letter to a public official; letter to a superior official, etc. Bring out the four essential parts of every letter.

Three months: Practice in writing — description of shop-work with special emphasis on the division of the composition into paragraphs. Engine- and boiler-room foundations, ammunition storage and boat cranes.

One month: Discussion and practice in writing according to the following outline: Planning, manufacture, and installation.

Three months: Composition on the turrets and bulkheads, hatches and armored decks.

Third Year

Six months: Considerable practice during this period should be devoted at this time to both oral and written descriptions. Effort should be made to correct every-day mistakes and develop the power to write lengthy descriptions in simple, direct, and concise language. Compositions based on method of propulsion, steering, procedure in building shell of ship, launching, etc.

Five months: During this period the apprentice should write reports and descriptions of what he is doing. Emphasis should be laid on accuracy and details in describing the building of a ship — designing, planning, manufacturing, and assembling.

One month: Written and oral composition on the economical and efficient methods of production.

The process of Americanization must follow along the lines of interest to the immigrant. He will learn English if he sees it is to his advantage. Therefore incentives must be offered. The greatest incentive to the recently arrived immigrant is an advancement in his work, increase in his earnings. The academic work must center around his daily occupation.

The English should consist of a series of graded lessons on the conservation, commands, names of parts of machines, tools, etc., that he uses in his work. This is the necessary English. As far as possible the work should be carried on through the activities of the shop or mill.[1]

[1] See page 177 for course of study for mill-workers.

Foreigners usually live in communities by themselves and seldom have occasion to use English. The club, the coffee-houses, the stores, and friends all use the mother tongue in conversation. Any attempt to teach English along general educational lines will fail at this period.

The desirable English is the English necessary to become a citizen. The foreigner should know the value of citizenship. This can be done by developing among the workmen social and industrial justice.[1]

ILLUSTRATIVE LESSONS IN INDUSTRIAL ENGLISH FOR NON-ENGLISH-SPEAKING WORKERS

Class in Cotton-Mill English

English on the Picker Machine: Picture or model of machine before the class

is : This is a picker
is called : This cover is called a "beater cover."
turns : The beater turns around rapidly.
be seen : The beater turns so fast that it cannot be seen.
breaks : It breaks the cotton into small parts.
loosens : The beater also loosens the dirt from the cotton.
be lifted : The beater cover must never be lifted until the
stops : belt stops.
did : The man in the picture did this.
lost : He lost his arm.

Good Rules

clean : Do not clean the beater when the machine is in motion.
clean : Clean the beater once or twice every day.
pick out : Do not pick out the picker droppings with the machine in motion.
stands : The man stands at the machine.
is : The machine is a picker.
is running : The picker is running.
has : The man's hand has four fingers and one thumb.

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[1] See page 179 for course of study.

has : The man has his hand on the lap.
will be drawn : The man's hand will be drawn in.
be broken : His fingers will be broken.
run : Do you run a picker?
must be : If you do you must be careful.
put : Never put your hand on the lap or roll.
lose : You will lose your fingers.

Picture or model of a loom before the class

am : I am a weaver.
have learned : I have just learned to weave.
run : I run six looms.
shows : This picture shows a man at a loom.
is : The warp is in its place.
are filled : The bobbins are filled with yarn.
holds : The magazine holds the bobbins.
feeds : The magazine feeds bobbins to the shuttles.
is : Everything is ready.
pull : I pull the lever with my hand.
weaves : The loom weaves cloth.
winds : The roll winds the cloth as fast as woven.
breaks : A thread breaks and the loom stops.
is fixed : The thread is fixed.
start : I start the loom again.

Most of the factory operations require semi-skilled and unskilled workers; each operation requiring only a short training. The only education that can be provided for unskilled workers is recreational education, and this is often provided by the manufacturers, under the head of "welfare work."[1]

Information relating to vocational life may be taught under the head of "civics." There is a very intimate connection between vocational success and good citizenship. Every successful citizen should be an efficient producer and should render service to the community. Included in the course should be material relating to the economic activities of the community, the history and opportunities, etc.; and all of the positions in the industries. In this way children may be taught their industrial obligations and opportunities. In fact, every subject in the course of study is susceptible of an industrial or vocational interpretation. Teachers have numbers of opportunities to speak to the children in terms of industrialism and citizenship. Frequent excursions should be made to industries to obtain first-hand information. History should be centered around the growth of the industries as successfully as it has covered literature, politics, and the careers of successful generals, statesmen, etc.

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[1] See page 253.

The content of information to be imparted to the apprentice or pupil, under the head of related trade knowledge, must consist of the underlying principles of English, mathematics, the sciences, drawing, materials, hand tools, power tools, transmission of power, etc. Each different shop project or practice should be analyzed into the hand tools, power tools, materials, processes, etc., the English, mathematics, sciences, etc., and the information desired placed under each column.

The arrangement of content of information to be imparted to a pupil in a vocational or apprentice school should be different from that of the regular school. The course in the regular school was founded on logical development, and a certain type of pupil accepted this development on faith. The pupil in the vocational school with his practical mind will not accept the arrangement on faith. He must see the value of knowledge and must have his interest aroused. The strongest interest is the desire to learn a trade; therefore the point of attack for all work, especially the academic work, should be around the vocational interest. The knowledge may be presented in the following order:

1. The knowledge absolutely necessary.
2. Show the value of more knowledge, then present the desirable knowledge.
3. The accomplishment or culture of the subject.

QUESTIONS FOR DISCUSSION

1. An instructor in shop English in an industrial school found that the pupils lacked interest in the *Autobiography* of Benjamin Franklin, after reading the first twenty pages. They desire to read trade magazines. Is the instructor justified in dropping the *Autobiography* for the trade magazine? Why?
2. Have the average pupils or apprentices in a secondary trade school much interest in general education? Why?
3. Why is it difficult to hold the attention of a group of apprentices in shop English for any length of time?
4. A pupil in an industrial continuation school objected to the study of grammar from a textbook. Explain why.
5. Why does a practical man appeal to the average pupil in a trade school more than the technical or academic teacher?
6. In many coöperative high-school courses pupils are obliged to spend the first year on high-school subjects. Is this a good plan? Why?
7. Investigations show that pupils in coöperative industrial courses frequently leave after learning the trade and become salesmen for mechanical lines. Explain this change.
8. Should technical journals be accessible to apprentices, tradesmen, and pupils? Where is a convenient place for these journals to be kept?
9. Explain some of the ways in which the element of citizenship may be taught to apprentices in the shop.

LIST OF REFERENCE MATERIAL FOR FUTURE READING

* "Teaching English." M. D. Lewis. *Outlook*, vol. 94, p. 651.
(A very effective method of teaching English.)
* "Oral Composition." E. M. Bolenius. *Education*, vol. 31, p. 449.
(The importance of training pupils in oral composition.)
* "On the Teaching of Written Composition." L. Cooper. *Education*, vol. 30, p. 481.
* "The Differentiation of High School Course in English." *Education*, vol. 31, p. 689.
(Need of different courses in English to meet varied needs of pupils.)
* *The Teaching of History and Civics.* Henry E. Bourne.
(A discussion of the most effective methods.)

CHAPTER XVI

MANUAL TRAINING VERSUS INDUSTRIAL EDUCATION

MANUAL training owes its existence primarily to the feeling among manufacturers and educators, after the Centennial Exhibition in Philadelphia, Pennsylvania, in 1876 that the various exhibits of industrial and trade products showed that the workmen of some European countries were superior to the American workmen. It was said that this superiority was due to the system of technical and industrial education in vogue in those countries. As a result of this opinion, school systems were asked to adopt a form of technical and industrial education that would meet this industrial deficiency among the American workmen.

The school authorities adopted a form of education called "manual training," based upon the schoolmaster's theory of industrial education; that is, to train the eye and hand so as to develop manual dexterity. The operation of woodworking was analyzed, and from this analysis a series of exercises in planing, marking, sawing, chiseling, etc., on wood, was developed. To illustrate: the child was taught to make a half-dozen different kinds of saw cuts on wood, and then to throw the cuts of wood away. In the same way joints of various kinds were made purely for practice. A similar course was constructed in metal-working. As time went on the public began to criticize this method of teaching — as not being "practical." Then method No. 2 was adopted to meet this objection; it consisted of exercises that made useful articles. These two methods rested on the belief that the mind was composed of faculties and that training (coördinating) the hand and eye was general, and that it would give a general handiness (manual dexterity) that would apply to all trades and industries. A boy who could use his hands to advantage in wood-working would be equally successful in other trades, such as tailoring.

After a number of years this theory was proven to be false. It was shown that hand training is not general, but is valuable only for the specific occupation in which the training is related. Method No. 3 (industrial method) was next introduced into the schools, and consisted in making simplified and primitive forms (objects) that would represent typical industries and trades, such as weaving raffia, to represent the textile industries, cobbling, the shoe industry, etc.

Method No. 4 (æsthetic method) was introduced to correlate the drawing and the manual work based upon the theory that the child is interested in constructing both beautiful and useful objects. Here was a method by which the child could express his ideas in beautiful and useful forms.

The correlation idea in method No. 4 was improved upon in method No. 5 (social method), when all forms of manual work were made the center of instruction for other subjects. The sixth and present method of manual training is called "industrial arts," and consists in illustrating the actual industries of to-day.

The history of manual training represents a very interesting development in methods of teaching. The first method held the interest of the child because he wanted to do something with his hands. Method No. 2 held his interest better because he is still interested in making something practical. Method No. 3 held his interest because his hand-work was more varied than before. Method No. 4 was a better method because it correlated the theory of drawing with the boy's greatest interest — hand-work.

Method No. 5 was an improvement because it increased the degree of correlation. Method No. 6 is a still greater improvement because the child is learning, by doing, about the industries of to-day that he will enter to-morrow.

Industrial arts should be introduced into every grade of the school system. Before the age of twelve or up to the sixth grade the work should consist of a variety of handwork, to give the child a variety of experiences in doing and learning many things, and not strive for a high degree of skill in any one form of the activities. The early life of the child consists of motor rather than reflective activities. The objects and materials used by the children up to this period should be large, as the physical development of the child will not allow him to work with small materials or fine instruments.

After the age of twelve opportunities should be provided for two classes of pupils: those who desire to continue their industrial arts (manual training) education, and those who desire to obtain a prevocational education. The present method of teaching manual arts or, better, industrial arts, may be improved and made a very important part of the general education of the child, by giving him a training in the study of the industries of to-day by making projects of present industrial value, and combining with it a discussion of the industry or trade showing the value of mathematics, drawing, science, etc. The work will have considerable educational value, depending much upon the way the subject is presented and the amount of interest shown by the teachers. For we must remember that mere motor activities may assist in mental development during the first few years of a child's life, and in the early period of the education of the feeble-minded, no evidence has ever been offered or presented showing that motor activities, pure and simple, without any other related thinking process, have any influence upon the development of the mind. It is possible to organize a course of study based upon either practice or observation, or both, of samples of various trades and industries; these can be selected, graded, and adapted to public school work, so as to stimulate the thinking process of the pupil, and in this manner promote both his physical and mental development.

It is clear that this cannot be done with the limited amount of time assigned to industrial arts at the present time. It is proposed that two hours a week be taken from the regular program, making in all five hours a week to be devoted to the subject of industries. This can be done without working a hardship to the present program, for it will mean simply a readjustment of some of the studies.

How to arrange such a course of study in industrial arts so as to have the proper development of motor and intellectual activities has raised some difficult pedagogical problems. It has been shown above that during the early stages of the elementary-school program very little reflective work should be provided with the hand-work. But as soon as the child enters the sixth grade he should begin to think about the hand-work and develop the habit of reading about the industries. To show that a great deal of time is wasted in our elementary-school program, as far as returns are concerned, consider the time devoted to geography, and how little knowledge of this subject is retained by the average adult. This is due primarily to the fact that geographical knowledge as often presented is a mere abstraction that is neither interesting nor clear to the average child.

A course in a study of industries presented in an interesting manner will arouse the vocational interests of the child. The excursion, observation, or hand-work may be the basis of instruction. The writer suggests four readers, with attractive titles to supply the related industrial information:

1. *The Farmer and His Friend.*
2. *Diggers of the Earth* (Miners).
3. *Makers of Many Things* (Manufacturers).
4. *Travelers and Traveling* (Commerce).

Each reader should contain information about the raw materials, the manufacture, trades, machines, etc., of an object that is familiar to the child, and that he uses at school or home.

The greatest educational value of industrial arts is obtained when the pupil is taught in the school shops, so that he works out his own plan as independently and completely as possible. The plan in the shops would be along this line: First, a general discussion of the purpose of the work: a study of the material to be used. Pupils should examine and compare various samples and models. Second, pupils with the aid of the teacher will work out plans. This can be done economically by the teacher working with the class as a whole. Pupils should be encouraged to look up all information on the subject. Third, each pupil should work out his own plans in writing, with drawings and calculations, and submit them to the teacher for approval. Fourth, the pupil should be allowed to proceed with the work.

However important manual training and prevocational education are, they must not be confused with industrial education — which aims to prepare a pupil definitely for a trade. It is a fact that industrial arts work or manual training was instituted to prepare pupils for the trades and industries, but the experience of twenty-five years shows us that it has failed to do so. What applies to industrial arts, applies equally well to household arts. In making this statement I know that there are isolated teachers doing splendid work in cabinet-making, printing, etc., under the head of manual training, and have sent boys directly to the trades, and there are some teachers doing manual training under the name of industrial work. Nevertheless I feel that this distinction applies to the general case.

The purpose of a course determines to a large degree the method of teaching and the kind of information imparted. An industrial course is to prepare specifically for a definite occupation, and it is necessary to train the pupil in the shortest time in skill and knowledge for that trade. The tools, equipment, and conditions in an industrial school shop must be similar to a commercial shop, the instructor a skilled mechanic of that trade, and the class must do commercial work under commercial conditions as nearly as possible. The work in an industrial school is largely individual and each member should be allowed to progress at a rate which is in accordance with his development. Since emphasis is on speed and skill, which means concentration on the part of the pupil to his work, it allows very little time to study procedure. His science, drawing, and mathematics are the science, drawing, and mathematics of his trade, so that specialization is carried on in all the school work. Emphasis is laid on the ability to do work, and not the talk about doing it. Classes are small — not over fifteen pupils at one time.

Industrial arts work or manual training, on the other hand, is a part of general education, and as such is governed by the existing general educational methods. Emphasis is laid on the complete comprehension of the scientific side of each subject. Larger classes, usually twenty-four, are allowed in industrial arts work, and the class usually works on the same project or exercise together.

Prevocational work is usually provided during the years from twelve to fourteen, and as the average child has not the physical development sufficiently to use his fingers for purposes of precision in some trades until he is at least fourteen years of age, and in most cases sixteen, the average pupil cannot do vocational work in a prevocational class.

Since the great majority of pupils must leave school, for economic and other reasons, when they reach the age of fourteen years, it is clear that whatever training a pupil receives for the work he is to do he must receive in the industrial arts, prevocational classes, and short unit industrial courses. That is the reason why those classes should be well developed, so that a course of study will be presented that will include every fundamental mode of utilizing the mind which the industries employ in the conduct of their affairs. This will give to the motor-minded boy interest and growth — which are necessary to power and self-confidence in doing the day's work. The problems that are to be studied should arise in a vital and natural way so that the motor-minded boy will see the need of study and memorizing in his school work.[1]

PREVOCATIONAL COURSE

The course of study for a prevocational school must be a varied one if it is to help boys and girls to find themselves. It should consist of an organized training in practical arts, which will include a variety of experiences fundamental to the life of the community. This includes wood-working, metal-working, printing, plumbing and sheet-metal work, and electrical construction, as they are all found in all communities, and possess content that can be easily adapted to school in the form of projects. This is different from a vocational course in wood-working, metal-work, or printing. Like the vocational work it will consist of a series of jobs, projects, or enterprises which in their accomplishment will give the boy an insight and appreciative understanding of fundamental processes in the more important industries of every community.[1]

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[1] See page 194 for course of study.

One half of the time in school should be given to related work in English, social studies, mathematics, science, for an intelligent understanding of civic and social responsibilities. The projects should be real commercial work, as is usually necessary in a school plant, in order to test the interests and capacities of the pupils.

The shop-work in a prevocational or industrial class should be arranged in a series of projects, each involving a new principle. A project card (see pp. 190, 191) should be used with each project. The card should contain the pupil's name, the pupil in charge of the project, senior pupil, and the helper's name, junior pupil. A space for the following marks should be left at the top of the card, related trade knowledge, and effort. These marks may be given by the teacher when the project or job is completed. The cards are kept on file as a matter of record; the date the job is started and the time it is finished, that the number of hours (total hours) may be calculated; the materials and tools ordered from the stock-room should be listed by the pupil after he has determined the proper equipment. The pieces should be obtained from the catalogue on file, at the tool-room window. The difference between stock and tools ordered and those used at the list prices (catalogue) represents the charge of the job outside of the labor. At the bottom of the card the cost of the job should be calculated according to the form of the standard wage. On the rear side of the card the drawing or sketch of the completed work should be made, and below, a description of the job or project.

Thus it is possible to mark on one card the related shop knowledge with complete data. The marks from the project card may be transferred at the teacher's leisure to a permanent record card called a "project marking card."

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[1] See page 193 for course of study.

Prevocational instructors. If the interest and capacity of a boy is to be successfully tested, the experiences given to him must be as near like the actual shop as possible, otherwise it lacks reality. In order to carry out this idea successfully, it is absolutely necessary to have instructors who possess not only a general acquaintanceship with, and knowledge of, the industries presented in the course of study, but they should give evidence of ability to make an intelligent study of the progress in methods and processes of work in industry, so that the school may be able to keep abreast of the times. This can be accomplished by the instructors working in industrial establishments during vacation periods. The uninterested teacher may be able to hold on in the regular school system, but the success of the prevocational work is dependent in such a large degree upon the teacher's power to hold and interest the pupils, and upon his qualities of adaptability, originality, initiative, and keen interest, that only the exceptional teacher should be employed.

The plan of the prevocational training in New York City is as follows: Pupils in the seventh and eighth grade classes are allowed to select a prevocational course which includes two groups of studies — the academic and the shop-work. The first includes the essentials of English, arithmetic, science, history, and geography. The second includes the theory and practice of mechanical drawing, free-hand drawing, electric wiring, garment design, joinery, sheet-metal work, machine-shop practice, printing, plumbing, and sign-painting.

The time allotment during the week is as follows:

Total time..................................	35 hours
Shop time..................................	15 hours

INDUSTRIAL ARTS OR PREVOCATIONAL WORK

Student or Apprentice in charge of job   Helper's name

Mark of workmanship   Mark for related trade knowledge

Mark of diagram   Effort

Job or project started   Finished   Total hours

Materials ordered   Catalogue   Price issue   Returned tools   Charge

Tools ordered

REAR SIDE OF CARD

Diagram of work

Description of job or project

Cost of Job

	Hr.	*Rate*
Mechanic's time		
	Hr.	*Rate*
Helper's time		
		Rate
Material, lb. or ft.		
Total		

INDUSTRIAL ARTS OR PREVOCATIONAL WORK

Name........................Class..............................
Born..........................Entered shop.... ....
Rating................ ......

Job or project	*Layout*	*Job*	*Effort*

Academic time	20 hours
English	5 hours
Arithmetic	3 hours
History, geography	2 hours
Science	2 hours
Physical training, hygiene	5 hours
Related drawing	3 hours

The academic material is correlated with the shop subjects and shop instruction. In order to do this effectively the academic instructors spend one hour daily in the shops consulting the shop teacher and pupils so that he is able to talk intelligently in the class work about the shop instruction. Pupils receive samples of different kinds of industrial work during the two years. The afternoons during the first nine weeks are devoted to machine work. Pupils showing unusually marked ability in the trade may continue in this branch, while those who show that they are not proficient change to electric wiring the second term of nine weeks. This scheme is continued every nine weeks in wood-working, sheet-metal work, commercial subjects, etc., until the pupil has found the trade that he is best adapted to follow.

The course provides for the presentation of instruction from the most elementary exercises to the finished job. The correlated work of the academic department has been planned with a view to giving it at a period when the work will be most timely. It is a significant fact that most correlated work of the printing class, particularly the formal English, possesses the double value of being cultural as well as technical.

In like manner the mathematics of printing, whether it be to find the number of ems in a given piece of work or determining the number of pieces that can be cut from a full sheet of paper, is of a kind that has a value other than its application to this trade. Experience has shown that this course, supplemented by a certain amount of individual instruction, will enable pupils possessing an aptitude to gain in one term a range of experience equivalent to that gained during two years in the average printing office.

Specimens show that the pupils have done considerable printing for their schools as well as for other schools in the vicinity. However, in no sense are schools in competition with the trade. If the schools did not have the printing equipment, the work would not have been done at all, because there would have been no funds available.

The following outline illustrates how the shop-work may be correlated with the academic work:

Printing

Practical work	*Shop-work*	*Correlation*
Learning arrangement of	Origin of printing	Mathematics
alphabet in type case	Spread of printing	Leads to pica
Making diagrams of type	Printing in education	Leads to inch
cases	and commerce, in	Points to lead
(a) California job case	newspapers and	Points to pica
(b) News cases	periodicals	Points to inch
Learning case	Knowledge of grammar	Picas to inch
Memory tests in location	and spelling essential	English
of alphabet in type case	Font of type	Spelling
Posture at case	Body type	Punctuation
Holding stick properly	Job faces	Proof-reading
Exercises "in picking up"	Name of type faces	Syllabication
properly and placing	Origin of names	History
into stick	Technical terms	First movable type
Exercises to develop	(a) Used in press-	Science
speed and uniformity	room	Type-making
of motion in setting	(b) Used in compos-	History
Spacing	ing-room	First Bible and
(a) Even spacing	Uses of equipment	other books
(b) Determining amount	(a) Composing-room	Science
of space between	(b) Press-room	Type-making
words		
(c) Space after "points"	Care of equipment	Mathematics
(d) Solid matter	(a) Composing-room	Point system

Practical work	*Shop-work*	*Correlation*
(c) Leaded matter	(b) Press-room	English
Justifying type in stick	Furniture	Spelling
	(a) Wood	Proof-reading
	(b) Metal	Punctuation
	Size of type and spacing material	Syllabication
		Mathematics
		Point system
		Points to em quad
		Points to en quad
		Points to 3 em space
		Points to 4 em space
		Points to 5 em space
		English
		Spelling

PLAN FOR PREVOCATIONAL EDUCATION

Tentative Courses of Study

A. Academic work. Approximately half time.

1. *English.* Language work based on reading, much of the reading to bear on the industries. Composition, dealing with the occupational work of the school, business correspondence, business forms, spelling, and penmanship. Aim to cultivate a love for reading.

2. *Arithmetic.* To be of a very practical nature, including fundamental processes, short methods used in business, business and trade arithmetic, with emphasis on immediate application to the industrial work of the school.

3. *Geography.* Chiefly industrial, and closely related to history.

4. *History.* Closely related to geography, and dealing with the industrial and commercial development of the city, state, and country.

5. *Civic and social duties.* Relation of the individual to the community, state, and country; relation of the worker to his work, to his employer, and to his fellow workmen; duties and responsibilities, both civic and social, with special reference to sanitation, personal hygiene, etc.

B. Industrial work. Approximately half time.

1. *Wood-working.* To consist principally of carpentry, including such other forms of work as may be called for by the projects undertaken. Study of tools; machines and structures, such as garages, poultry-houses; problems in framing, truss construction, and repair work, with emphasis on the latter.

2. *Metal-working.* To consist of work in hot and cold bar metal and sheet metal. Practical problems in repairs and construction which develop in the equipping of the school, will supply work for some time. This will include such work as the making of brace and angle irons, bolts, machine and belt guards, simple tools, pipe cutting and threading, metal parts of electrical and other apparatus.

   In addition to this, the students should take apart and assemble the old machines, endeavoring to find out how they work and why they work. Study carefully the principles of the automatic machine and the method of conveying power through machines to the point of doing the work, the intention of this work being to familiarize the students with the general principles of machine construction.

3. *Printing and binding.* To consist of the simpler forms, mainly the printing of forms, cards, announcements, etc., required for the school, this work to be supplemented by special work in English, proof-reading, design, and color harmony.

4. *Electrical construction.* To consist of elementary work in battery construction, magnetism, induction, small motor and dynamo construction, wiring, electrical measurements, and testing. Experiments with batteries, induction coils, and the wiring of bell, telegraph, telephone, and other circuits, will be worked out on specially constructed frames.

5. *Drawing.* To be elementary in character, but practical and related directly to the projects undertaken by the pupils in the various shops. To consist of both free-hand sketching and mechanical drawing of the common parts of machines such as nuts, bolts, screws, etc.

Program of Classes

	First year		*Second year*	
	Section 1	*Section 2*	*Section 1*	*Section 2*
Mondays, Wednesdays, Fridays				
Mornings	Shop-work	Book-work	Shop-work	Book-work
Afternoons	Book-work	Shop-work	Book-work	Shop-work
Tuesdays and Thursdays				
Mornings	Book-work	Shop-work	Book-work	Shop-work
Afternoons	Shop-work	Book-work	Shop-work	Book-work

While section 1 of the first class is receiving instruction in the wood-working shop during the first half-year, section 2 is in the printing shop. During the second half-year the two sections are reversed. Similarly, the two sections of the second-year class alternate between the metal shop and the electrical shop. In all cases one half of each day is spent in the shop and the other half in book-work, as already noted.

A program for manual training usually includes a double period or one half the morning or afternoon. The academic work is not usually correlated with the shop activities.

Instructors in manual training are usually graduates in the manual training courses of colleges and normal schools. Many have received both their professional and shop training in the normal and college classrooms and shops. Naturally they bring into the school shop the general educational methods and not the commercial methods of the industrial world, which latter are so necessary in training a boy to be a mechanic. It is seldom that the manual training instructor is willing to go into the commercial shop after he has begun to teach in order to get the commercial shop training. This lack in manual training instructors of commercial shop experience is the principal reason why they are not usually employed in vocational and prevocational schools. Experience shows that it is possible to take an experienced mechanic from the industrial world and supplement his experience with sufficient knowledge on principles and methods to make an effective shop instructor and that it is not a satisfactory plan to train industrial teachers by giving them all their shop experience in a school shop,

MANUAL TRAINING OUTLINE

SUGGESTIVE COURSE OF STUDY IN WOOD-WORKING FOR NINTH GRADE

	Purpose of project	*Processes involved*	*Demonstration*
PROJECT 1 *Footstool*	Review of the fundamental tool processes taught in the previous grades adapting it to adult standards.	Mechanical drawing of project Bill of stock Problem of cutting up stock board Cabinet-makers method of working at the bench.	Present method of cabinet-makers working at the bench.
PROJECT 2 *Magazine-stand*	A small piece of furniture involving simple joint construction	Free hand working sketch showing proportions and dimensions Mechanical drawing from approved sketch Use of power saw and planer to size stock	Use of power saw and planer. Talks on constructive design and difficult construction. Economy of labor.
PROJECT 3 *Writing-desk*	More advanced piece of construction involving drawer construction	Use all wood-work machines and do as little bench work as is practicable	Study of the uses, structure, and classification of the different woods
Sewing-cabinet	Cabinet involving paneling and door construction.	Wood-working machines	Cabinet design and construction details. Factory methods
Refinishing of a piece	The method of finishing of wood.	Finishing of wood such as staining, filling, waxing, varnishing, and mixing stains.	Stains — water, oil, spirit fuming, other chemical actions. Fillers — liquid, paste, varnishes, shellac.

QUESTIONS FOR DISCUSSION

1. The city officials of a large community recently decided to do away with manual training in the school system, on the ground that it was expensive and the schools were not obliged to teach it. Were the school officials justified?
2. Explain why the manual training in the general high school of a textile community usually teaches wood-working and metal-working, and ignores the most important industrial activity of the city?
3. Should cobbling be taught in the grades?
4. Industrial arts are often used instead of manual training to-day. Why?
5. A principal of a large elementary school desires printing taught in order to have plenty of forms for the office. Is this good pedagogy?
6. An instructor in wood-working in a prevocational school has made out a definite course of study, but is unable to follow same, on account of the demand for flower-pot stands, and other improvements for the school. The principal of the school approves of these demands. What are the advantages and disadvantages of such a plan?
7. In the poorer sections of a large cosmopolitan city a number of prevocational classes were established, while none were formed in the wealthier parts of the city. Is this fair to the citizens?
8. Is it possible to teach trades in a prevocational school?
9. A principal of a large school finds a number of boys who are about to leave school. He places them in a prevocational class in machine-shop work, and insists that they be taught how to run a lathe in order that they may secure a position later. Is he justified in doing this?
10. How will manual training or industrial arts assist in vocational guidance?
11. An instructor in wood-working in a high school makes a few chairs for the school, and he states he is doing trade work and should secure state aid. Should the class receive state approval?
12. Explain why boys like to work in wood-working.
13. Should an industrial arts course in a school system include all forms of industrial activities open to the boy of that community?
14. Should girls be allowed to take metal-working in a high school?
15. A teacher of pattern-making claims that a course in pattern-making "teaches pupils to be accurate and careful." Does psychology justify this statement?
16. A community cannot afford to support both an industrial and a prevocational school. Which one should be omitted? Why?
17. State the educational values of the following: (a) forging in the technical course in a high school; (b) sign painting in a prevocational course; (c) plumbing in an evening trade school; (d) hand weaving in the third grade; (e) refinishing a piece of furniture in the eighth grade.

LIST OF REFERENCE MATERIAL FOR FUTURE READING

* *What can the Grade School do for Industrial Education?* A. Garlin Spencer. National Society for the Promotion of Industrial Education. Proceedings, 1908.

(Need of reorganization of grade work so as to contribute to industrial education.)

** "Three Stages in Industrial Education." *Manual Training and Vocational Education Magazine*, January, 1916.

** *The Place of Industries in Elementary Education.* Katherine Dopp.

(Shows the relationship between industries and the social development of the workers.)

** *Hand and Eye Training.* Waldemar Goetz.

* *The Educational Value of Manual Training.* C. M. Woodward.

* "Relation of Manual to Industrial Education." C. R. Richards. *Manual Training and Vocational Magazine*, October, 1907.

(Distinction between manual and industrial training.)

* Report on the Organization and Extension of Prevocational Training in Elementary Schools. W. L. Ettinger. Department of Education, New York City.

(A valuable contribution. Methods and courses of study are given.)

CHAPTER XVII

SHUNT, SERIES, AND COMPOUND WINDING

§ 1. Methods of excitation of the field-magnet. Separate excitation.—The excitation of the electro-magnet of a dynamo is, in general, effected either (1) by coils connected to a separate source of current, the machine being then said to be "separately excited;" or (2) by coils forming a shunt to the external circuit, the dynamo being then known as a "shunt" machine; or (3) by coils in series with the external circuit, when the dynamo is called a "series" machine; or (4) by both shunt and series coils in combination, a method known as "compound winding."

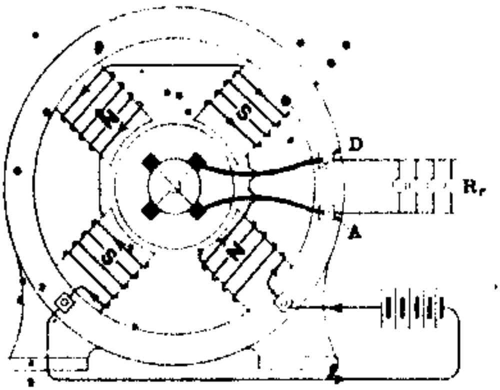

FIG. 284.—Separately excited dynamo.

The excitation of a machine from a separate and entirely external source of electrical energy is the most obvious method, and was the one first adopted in practice, a small dynamo with permanent magnets of steel being used to furnish current for exciting the field-magnet of a larger dynamo. Fig. 284 shows a *separately excited machine*, the electric circuit of the magnetizing coils being entirely distinct from the circuit of the main dynamo; in the diagram the main external circuit, R_e, is indicated by incandescent lamps strung in parallel across from the positive to the negative lead. The source of the magnetizing current is represented by a battery of cells, but, of course, is usually a separate continuous-current dynamo. The principle is still retained in connection with alternators, a separate "exciter" furnishing continuous current for their excitation, and in special cases of continuous-current dynamos when their magnetization would otherwise tend to become unstable. The calculation of the field-winding for separate excitation is made at once from equations (124–6).

§ 2. Shunt excitation.—The second step in the order of development was made when it was suggested that a part of the electrical output delivered by the main dynamo might be used to maintain or increase the magnetism of its own field-magnet. This was, however, only possible if the machine were furnished with a commutator by which the current was commuted into a steady flow in one direction, and was thus rendered suitable for magnetizing purposes. Two distinct methods were then invented by which this suggestion was realized.

By the first, magnetizing coils were arranged as a *shunt* to the external circuit proper; thus, in Fig. 285, from the brushes of the dynamo two paths, R_s and R_e, are presented, and the armature current divides into two portions, the relative magnitudes of which will vary inversely as the resistances of R_e and R_s; while the one portion of the total armature current flows through the external circuit R_e, wherein the useful electrical energy is manifested, the other is shunted through the magnetizing coils, and both reunite to flow through the armature. The voltage on the shunt is, of course, the same as that on the external circuit, since the same terminals, A and D, serve for both. If the resistance of the shunt, R_s, be relatively high as compared with R_e, only a small proportion of the total energy developed will be absorbed in exciting the field-magnet, and this is the case under load, owing to the resistance of the external circuit being then comparatively low. Hence the shunt coils consist of a large number of turns of small wire, and are represented in the diagram by fine lines.

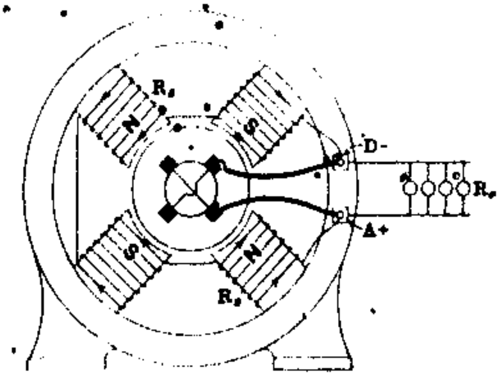

Fig. 285. Shunt wound dynamo.

§ 3. Series excitation.—By the second alternative method, magnetizing coils are arranged in *series* with the external circuit, and the whole of the armature current passes alike through the turns of the field-magnet coils, R_m, and the external circuit, R_e (Fig. 286). A portion of the total voltage developed at the brushes is expended in the magnetizing coils, and the remainder is available for useful work at the terminals, B, D, to which the external circuit is applied. If the resistance of the series coils, R_m, be low as compared with the resistance of the external circuit, the percentage of energy absorbed in the field will be small as compared with the useful output; on this account the series coils will usually be a few turns of thick copper strip, and are so represented in the diagram. The number of ampere-turns on the magnet of the dynamo may be the same whether it be shunt- or series-wound, since in the one case a small current flows through a large number of turns, and in the other case a large current flows through a few turns; and in both cases the amount of energy absorbed in securing any given number of ampere-turns is simply a question of the amount of copper in the field-coils.

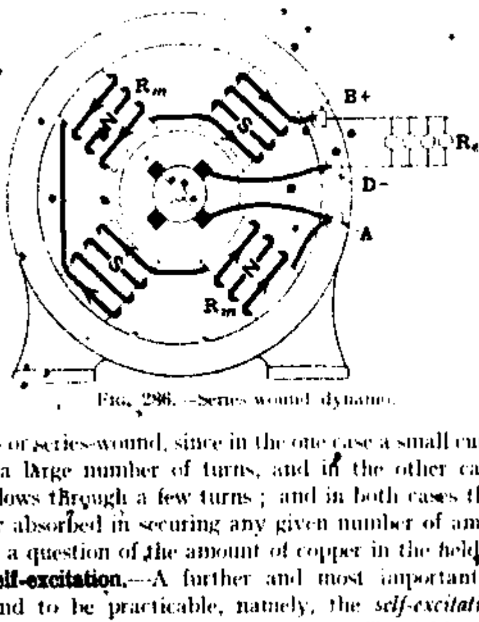

FIG. 286.—Series-wound dynamo.

§ 4. Self-excitation.—A further and most important step was next found to be practicable, namely, the *self-excitation* of the machine, whether shunt- or series-wound. The field-magnet of a dynamo is slightly magnetized, even when the machine has ceased running; it may then appear to be perfectly demagnetized by its failing to attract, say, a bunch of keys held near the poles, but a more delicate test will show that both forged and cast iron or steel retain a certain amount of magnetic flux (Chapter XIV, § 4). The presence of this feeble residual flux is sufficient to start the process of self-excitation, so that when the armature of either Fig. 285 or Fig. 286 is rotated, the active conductors cut the residual lines, and a small E.M.F. is thereby set up within the winding of the armature. If the brushes are "down" on the commutator, and a closed circuit is thereby made, this small E.M.F. sends a feeble current through the magnetizing coils; the ampere-turns of the latter, although as yet they may be small, still serve to increase the number of lines passing through the armature, and these, as they are cut by the wires, produce an increased E.M.F.; the exciting current is thereby in turn increased, and its increase is again followed by a further increase in the flux and E.M.F. Thus the magnetism gradually grows, the increments becoming less and less as the iron of the field-magnet becomes more and more saturated. The time taken by the "building up" process will vary from a few seconds in a small machine to a minute or more in a large magnet, but after a short time a small increase in the exciting current produces very little increase in the flux; finally, for a given speed of rotation the voltage and exciting current reach a settled state, and the machine will run for any length of time, maintaining its own constant flux. Thus the presence of residual flux renders it unnecessary to impart to the field magnet any initial excitation, and the continuous-current machine becomes self-exciting by the mere rotation of the armature. One difference, however, between the shunt- and the series-machine will be apparent from their respective diagrams. In the latter case the external circuit must be closed before the process of excitation will begin, since the circuit of the field-coils is only completed through the external circuit. In the former case, if an external circuit of very low resistance be closed on the brushes, so small a portion of the feeble initial current will be shunted through the magnet-coils that the machine may fail to excite. Hence, in the shunt machine, the excitation is most quickly and surely obtained if the external circuit be left open until the magnet is thoroughly excited.

It only remains to remark that even when a machine has just come from the workshops, and is run for the first time, there is usually sufficient residual flux in the magnet, due to the effect of the earth's magnetic field or of other magnetic bodies upon it during the process of its manufacture, to enable it to excite itself. The first excitation may, however, require a higher speed than will be subsequently necessary, and in cases of large shunt machines, running at slow speeds, separate excitation may have to be resorted to in the first instance.

§ 5. Energy stored in the excited field.—When once the machine is normally excited, and is running under settled conditions, the energy spent in the magnetizing coils is entirely converted into heat; but during the process of creating the magnetic field a certain amount of energy is absorbed which is given back as the field demagnetizes. If the circuit of a series-wound dynamo be opened while it is running, the stored-up energy reappears in the form of a spark at the switch; the rapid collapse of the lines of flux which circle through the turns of the field-coils generates a high E.M.F., which tends to keep up the strength of the current; and if the field be powerful and the turns encircling it be numerous, the intensity of the spark is great. In the case of a shunt-wound dynamo the opening of the external circuit does not interrupt the flow of the shunt current round the coils; the stored energy discharged at the switch is then chiefly that of the external circuit. Owing, however, to the large number of turns in the shunt, the effect of suddenly breaking the magnetizing circuit is even more marked than in a series machine. Thus, if a person accidentally lifts the brushes of a large shunt machine running on open circuit, the self-induced E.M.F. may rise to thousands of volts, may damage the insulation of the machine, and, further, may give perhaps a fatal shock. If the machine be running on a closed circuit, say, of incandescent lamps, the person would be less liable to receive such a severe shock, since the so-called "extra-current" is discharged through the external circuit, and causes the lamps to flash up momentarily. In order, therefore, to open the shunt circuit of a machine when running, a shunt-breaking switch is necessary, in which at the moment of opening a non-inductive resistance is closed upon the terminals of the shunt.

§ 6. Determination of shunt-winding.—The application of the formulæ of Chapter XVI to the design of the field-winding of the shunt machine is easy. Let V_t be the terminal or external voltage which the machine is required to give when supplying its full external current; then the difference of potential on the ends of the shunt[1] is likewise V_t, and it is only necessary to substitute its value for V_s in equations (124-5) in order to determine the necessary area or diameter of wire. In order further to determine the number of turns and weight of wire, it is necessary to know, at least approximately, the rate in watts at which energy may be expended in the field-coils.

While, however, the necessary size of wire is rigidly determined, there is, in fact, no hard-and-fast rule for deciding the weight that is to be used, and this must be left to the designer's judgment. If a large quantity be used, the weight and cost of the machine are increased, while if a smaller quantity be used the heating of the field-coils is greater, and the efficiency of the machine is decreased. A further disadvantage which arises when the weight of copper is reduced is that there is a greater difference between the resistances of the shunt when cold and when hot, owing to its rise of temperature being greater; this difference causes a difference in the shunt current for the same terminal voltage, and therefore in the excitation and total flux produced, so that when the dynamo runs at a constant speed the E.M.F. induced is greater at starting than it is after it has run for several hours continuously and has attained its final temperature. If this difference be great, it will necessitate an alteration in the speed of rotation in order to maintain the correct voltage, or it must be corrected by means of a variable rheostat in series with the shunt. Difference of temperature is minimized by the winding of the shunt coils in separate sections with intervening air-ducts through which the air is brought into contact with the more heated central parts, as in Figs. 280, 281; but, on the other hand, it has to be borne in mind that, as compared with a single coil filling the whole of the bobbin-length, the lesser number of turns and weight of wire are always obtained at the expense of a slightly lower efficiency. The settlement of the rate in watts at which energy may be expended in the shunt coils depends, therefore, upon their allowable heating, and upon the efficiency which the dynamo is to have; from both considerations combined, experience enables us to fix upon a preliminary estimate from which the completed design need differ but little. In practice, the loss of energy in the field of a shunt machine varies from about 0·75 per cent. of the output in a 1,000-kilowatt machine, 1·5 per cent. in a 100-kilowatt machine, to 7 or 8 per cent. in a 4-kilowatt machine. The heating question will be more fully discussed in Chapter XXI. If it be settled that W watts may be lost in the field-winding, then $W = V_s \times I_s$ watts, and $I_s = V_s/R_s$, whence the resistance of the shunt and its composition can be at once determined. The preliminary result thus arrived at should only require such slight revision as will lead to the winding forming a complete number of layers.

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[1] Unless there is a rheostat in circuit, as will be described in § 8.

§ 7. Determination of a shunt-winding with two sizes of wire.—As stated in Chapter XVI, § 16, there is only one diameter of wire which will give a specified number of ampere-turns for a given applied voltage V_s at its ends, if the whole of the coil is wound with wire of the same gauge. It is, however, often desired to make up a composite shunt winding out of two sizes of wires. Any size of shunt wire can be specially drawn, but for manufacturing reasons it is advisable to adhere to certain standard sizes of wire which are held in stock. Given two sizes, one of which is larger and the other smaller than the correct diameter, they can be wound in such proportions as to produce the same magnetizing result as the correct intermediate size. The use of two gauges of wire in series implies a different rate of heat-generation in them owing to their unequal current-density, but in practice, if the two sizes do not differ greatly, this leads to no disadvantageous result.

To determine the necessary proportions by trial and error is usually a somewhat lengthy process, and the calculation may be much shortened by attention to the following points:

From equation (125) the AT of any coil wound with wire of area a sq. inches is

$$\frac{V_s \times 1{,}000 \times a}{0.02445 \times l_s \times k}$$

When two sizes of wire are to be employed, let the suffixes l, s, c indicate respectively the large, small and correct sizes of wire. The current through the combination of wires is

$$\frac{V_s \times 1{,}000}{0.02445\left(\frac{T_l \times l_{tl} \times k_l}{a_l} + \frac{T_s \times l_{ts} \times k_s}{a_s}\right)}$$

and this when multiplied by $(T_s + T_l)$ must give

$$\frac{V_s \times 1{,}000 \times a_c}{0.02445 \times l_s \times k}$$

The turns T_s and T_l must now be expressed in terms of the number of turns of either the larger or the smaller wire which will fill the entire winding space of sectional area A. Let the larger wire be taken and let T_l' be the number of turns of it which will fill the area A.

The true number of turns of the larger wire when a part A_s of the winding space is filled with the smaller wire instead of the larger wire is then

$$T_l = T_l' \cdot \frac{A - A_s}{A}$$

and the true number of turns of the smaller wire is

$$T_s = T_l' \cdot \frac{A_s}{A} \cdot \frac{a_{1l}}{a_{1s}},$$

where a_{1l} and a_{1s} are the areas which one turn of each of the two sizes of wire occupies when insulated and after taking into account the interstices between the wires.

The total turns are therefore

$$T_s + T_l = T_l'\left\{1 + \frac{A_s}{A}\left(\frac{a_{1l}}{a_{1s}} - 1\right)\right\}$$

or since $A_s = T_s \cdot a_{1s}$ and $A = T_l' \cdot a_{1l}$

$$= T_l' + T_s\left(1 - \frac{a_{1s}}{a_{1l}}\right)$$

$$= T_l' + T_s\left\{1 - \left(\frac{d_{1s}}{d_{1l}}\right)^2\right\}$$

since whatever the conditions of bedding, a_1 is ∝ d_1^2, where d_1 is the insulated diameter of the wire.

Identifying k_1, k_2, and k_3, it is found by substitution that

$$T_s = T_1' \cdot \frac{\left(\frac{d_1}{d_s}\right)^2 - \frac{l_{xl}}{l_x}}{\left(\frac{d_1}{d_s}\right)^2 \cdot \frac{l_{xs}}{l_x} - \left(\frac{d_1}{d_l}\right)^2 + \left(\frac{d_{1s}}{d_{1l}}\right)^2 \left\{\left(\frac{d_1}{d_s}\right)^2 - \frac{l_{xl}}{l_x}\right\}}$$

$$T_l = T_1' \cdot \frac{\left(\frac{d_1}{d_s}\right)^2 \cdot \frac{l_{xs}}{l_x} - \left(\frac{d_1}{d_l}\right)^2}{\left(\frac{d_1}{d_s}\right)^2 \cdot \frac{l_{xs}}{l_x} - \left(\frac{d_1}{d_l}\right)^2 + \left(\frac{d_{1s}}{d_{1l}}\right)^2 \left\{\left(\frac{d_1}{d_s}\right)^2 - \frac{l_{xl}}{l_x}\right\}}$$

When the coil is divided into sections so that the mean length of a turn in each section is the same, and $l_{xl} = l_x = l_{xs}$, the equations are immediately soluble. As a general rule, it suffices in this case to calculate the relative widths of the sections of the two wires. If y_s = the fraction of the net winding length (after deducting any radial air-spaces) which the small wire must occupy,

$$y_s = \frac{1}{1 + \left(\frac{d_{1l}}{d_{1s}}\right)^2 \cdot \left(\frac{d_1}{d_s}\right)^2 \cdot \frac{d_l^2 - d_s^2}{d_1^2 - d_l^2}} \quad . \quad . \quad (131)$$

In this expression the differences in the squares require to be worked out with accuracy.

But if one size of wire is wound above the other, $\frac{l_{xl}}{l_x}$ and $\frac{l_{xs}}{l_x}$ in the previous equations must be approximately estimated, as roughly indicated below. Under average conditions of depth, etc.,

	$\frac{l_{xl}}{l_x}$	$\frac{l_{xs}}{l_x}$
(a) With the small size wound on the inside,		
and nearly right in size	1·17	0·98
half and half in depth	1·08	0·91
large size nearly right	1·02	0·82
(b) With the small size wound on the outside,		
large size nearly right	0·93	1·17
half and half in depth	0·91	1·08
small size nearly right	0·82	1·02

Since with the same winding length $T \propto n/d_1$, where n is the number of layers, the ratio between the numbers of layers of the two sizes is

$$\frac{n_s}{n_l} = \frac{d_{1s}}{d_{1l}} \cdot \frac{\left(\frac{d_1}{d_s}\right)^2 - \frac{l_{xl}}{l_x}}{\left(\frac{d_1}{d_s}\right)^2 \cdot \frac{l_{xs}}{l_x} - \left(\frac{d_1}{d_l}\right)^2} \quad . \quad . \quad . \quad (132)$$

The ratio $\left(\frac{d_1}{d_s}\right)^2$ need not necessarily exceed $\frac{l_{xl}}{l_x}$, since if the smaller wire is wound inside and will at a certain thickness give the required number or more than the required number of AT, the function of the larger wire at its larger mean turn is to *reduce* the AT. But if this is the case and the numerator of the above equations becomes negative, $\left(\frac{d_s}{d_e}\right)^2$ must exceed $\frac{l_{zs}}{l_z}$, which makes the denominator also negative. When the sizes are thus so nearly commensurate with their respective mean turns, the equations cannot be solved with sufficient correctness on the slide rule, the differences being too small to determine accurately. It is therefore best to wind the smaller wire outside, for purposes of calculation, since it is practically a matter of indifference which course is pursued. Under these circumstances $\left(\frac{d_l}{d_e}\right)^2$ always exceeds $\frac{l_{zl}}{l_z}$ and $\frac{l_{zs}}{l_z}$ exceeds $\left(\frac{d_s}{d_e}\right)^2$ which gives a clue to the right values to be inserted for the ratios $\frac{l_{zl}}{l_z}$ and $\frac{l_{zs}}{l_z}$.

The following simple approximate formulæ have been developed by Mr. R. G. Jakeman[1] to determine directly the winding depths of the two sizes of wire when one is wound above the other.

1. If the large size is wound first

$$\frac{x}{x_l} = 1 + 0{\cdot}45\,\frac{a_l - a_e}{a_e - a_s}$$

2. If the small size is wound first

$$\frac{x}{x_l} = 1 + 1{\cdot}0\,\frac{a_l - a_e}{a_e - a_s}$$

where x and x_l are the total winding depth and the depth of the large size respectively. These formulæ give good results in practice for any size of coil, whether round or rectangular.

When the wires as usual are not far removed from one another in size, the differences are so small that the numbers of turns for a given depth of winding can be varied through a wide range with practically little effect on the total AT which the combination yields.

§ 8. Example of shunt-winding calculation.—To illustrate the above, the winding for the 21" × 11" dynamo of Chapter XVI, § 9, as a shunt machine will now be worked out in detail. A shunt-wound dynamo is almost invariably furnished with a rheostat or resistance in series with the magnet winding, for the purpose of regulating its voltage; the coils of such a rheostat can be successively thrown into or out of the shunt circuit, and since for a given voltage at the brushes the exciting current can be thereby reduced or increased, the voltage of the machine can be lowered or raised by successive small steps. It will be assumed in the present case that a shunt rheostat is to be used, so that the electrical connections of the machine will be as diagrammatically shown in Fig. 287, and the current in the shunt is $I_s = \frac{V_b}{R_s + R_r}$, where R_r is the resistance corresponding to the particular contact on which the arm of the rheostat rests. Under these circumstances at full load, and when the machine is heated after a prolonged run, it will be advisable to retain a small margin of resistance in the rheostat; in other words, the full voltage at the brushes will not be used to excite the field-magnet. It will be remembered from Chapter XVI, § 16, that, when once the gauge of shunt wire has been selected and the coils wound, the ampere-turns are not increased but rather reduced by winding on more turns, while a limit to the removal of turns is quickly reached through the overheating of the coil which results. But if one or two steps of resistance in a rheostat have been held in reserve, should it become necessary to make up any small deficiency in the calculated ampere-turns or to cover any variation from strictly normal conditions, the last steps can be cut out and the voltage thereby raised slightly. But on the other hand, the difference between the terminal voltage at the brushes V_b, and that applied to the terminals of the field-coils, V_s, *i.e.* the loss of volts over the rheostat at full load, or $V_b - V_s$, must be kept small, so as not to impair appreciably the efficiency of the machine. In the present case, therefore, V_s will be taken as about 2½ per cent. less than V_b, or, say, 225 out of the 230 volts at the brushes or terminals of the external circuit.

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[1] "A Direct Method of Calculating Shunt Field Coils having Two Gauges of Wire," *Electr.*, 21st Nov., 1919.

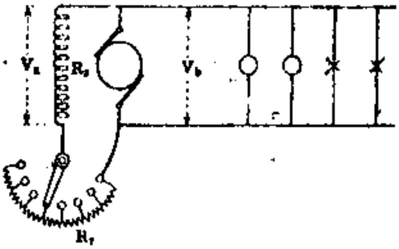

Fig. 287.—Adjustable rheostat in shunt circuit.

With the same loss of volts over the armature resistance and brushes as in Chapter XVI, § 9, the induced E.M.F. must now be 238 volts, or slightly less than before, since no part of the field-winding is in series with the armature; the necessary flux is therefore $\Phi_a = \frac{238 \times 60 \times 10^8}{450 \times 500} = 6{\cdot}35 \times 10^6$, and the total ampere-turns on the four poles to give this flux is from Fig. 274, $AT_f \times 2p = 4 \times 9{,}500$.

The diameter of the pole being 9¼", the inside diameter of the bobbin over the wood strips running axially down the magnet-core, after the fashion of Fig. 280, will be 9¾". A depth of winding of 2⅝" may be assumed, so that the mean diameter of a central turn will be 12⅜", and its length $l_s = \pi \times 12{\cdot}375$ inches $= 1{\cdot}08$ yard.

With the assumed thickness of winding, $\frac{l_o}{l_m} = \frac{9{\cdot}875 + 5}{9{\cdot}875 + 2{\cdot}5} = 1{\cdot}2$, and $\sqrt{\sigma} = 0{\cdot}925\,\frac{d}{d_1}$ will be about 0·8. As will be explained in Chapter XXI, if the coil were closely wound without any ventilating channels, a ratio of about 0·5 watt per square inch would give a surface rise of temperature of about 45° F., and the ratio of the mean rise to the surface rise would be, say, 1·72, so that from Chapter XVI, § 16, assuming the temperature of the engine-room to be 70° F. while the standard temperature of the wire table is 68° F., $k = 1 + 0{\cdot}0022 \times 79{\cdot}5 = 1{\cdot}175$, and $\sqrt{\frac{k}{\xi\epsilon}} = \sqrt{\frac{1{\cdot}175}{0{\cdot}5}} = 1{\cdot}53$. Since each coil has to give 9,500 ampere-turns, by equation (129),

$$\sqrt{1{\cdot}2L^2t + 2Lt^2} = \frac{9{\cdot}5}{1{\cdot}21 \times 0{\cdot}8} \times 1{\cdot}53 = 15$$

and with 2½″ depth of winding $L = 6{\cdot}82''$.

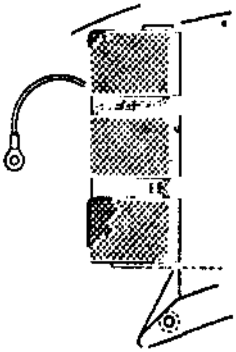

Fig. 288.

The above gives a first idea of the necessary length of coil, and will hold good equally in the present case when the coils are to be divided up into sections with air-canals between them. The effect of this construction will be to reduce the value of k and at the same time to increase the watts per square inch that may be allowed for the same surface rise; thus, as in Chapter XVI, § 16, k may be taken as 1·16, and 0·64 watt per square inch may be allowed, the gross length of coil being reckoned in the cooling surface. It results that, even when two air-canals each ⅜″ wide are added to divide the coil into three sections (Fig. 288), its gross length may remain 6·8″. It will be assumed, therefore, that the above calculations or the known design of the magnetic circuit, as in Fig. 266, have led to an axial length of pole of 7·3″, a surplus of ¼″ being allowed at each end of the coil.

The several shunt coils, one on each pole, are almost invariably connected in series, so that by equation (124)

$$\omega' = \frac{225 \times 1{,}000}{38{,}000 \times 1{\cdot}08 \times 1{\cdot}16} = 4{\cdot}72 \text{ ohms per } 1{,}000 \text{ yards},$$

and the necessary diameter of the shunt wire is by equation (128)

$$d = \frac{0{\cdot}176}{\sqrt{4{\cdot}72}} = 0{\cdot}0813''$$

The net winding length is $7{\cdot}3 - 1{\cdot}25 = 6{\cdot}05''$, and each of the three sections will be, say, 2·02″ long. In order to illustrate the procedure that would be followed in working out the details of the coils, a winding with the above single size of wire will first be completed as follows. The number of turns in a layer of one section will be $\frac{2{\cdot}02}{0{\cdot}0963} = 20{\cdot}9$. Strictly speaking, one turn must be deducted from this quotient, which gives 19·9, or 59·7 per layer of the three sections. With a depth of about 2·5″ there will be 28 layers, since with allowance for bedding we have by equation (128)

$$0{\cdot}9 \times 28 \times 0{\cdot}0963'' = 2{\cdot}43''$$

The total number of turns on a complete bobbin will be, therefore, $28 \times 59{\cdot}7 = 1{,}670$, or 6,680 in all on the four bobbins. The mean length of a turn being $l_s = (9{\cdot}875 + 2{\cdot}5)\pi = 38{\cdot}8$ inches $= 1{\cdot}08$ yard, the total length of wire is 7,215 yards, and its resistance at 68° F. $= 7{\cdot}215 \times 4{\cdot}72 = 34$ ohms, or when heated 34 ohms $\times\ 1{\cdot}16 = 39{\cdot}45$ ohms. In order to give a total of 38,000 ampere-turns the current must be 5·7 amperes, corresponding to the assumed $V_s = 225$ volts, and to a loss of energy in the shunt winding at the rate of $5{\cdot}7 \times 225 = 1{,}280$ watts. The perimeter of the outer layer will be $(9{\cdot}875 + 5)\pi = 46{\cdot}6''$, and the over-all length of the coil being 6·81″, the total cooling surface of the four coils (measured as in Chapter XV, § 5) will be

$$\begin{aligned} 46{\cdot}6 \times 6{\cdot}81 &= 318 \\ 2 \times 2{\cdot}5 \times 38{\cdot}8 &= 194 \\ &\ \overline{512} \times 4 = \text{say, } 2{,}000 \text{ sq. inches.} \end{aligned}$$

As will be explained in Chapter XXI, the ratio $\frac{1{,}280}{2{,}000} = 0{\cdot}64$ watt per square inch will, in the present type of construction with well ventilated coils, give a surface rise of temperature of about 48° F., or sufficiently near to our assumed amount. The design may therefore be proceeded with, since the assumed depth of winding tallies with the requirements in regard to heating.

It will next be assumed that for manufacturing reasons we are limited to No. 14 S.W.G. = 0·080″ diameter, and a size intermediate between Nos. 14 and 13, say ·085″ diameter. The diameter of the double-cotton-covered wire with 15 mils insulation will be in the two cases 0·095″ and 0·100″. Substituting these values in equation (131), y_s is 0·7, and in view of the small difference between the wires, there will be but little effect if its proportion of the total length of the winding is reduced to two-thirds. Three sections of equal axial length have a good appearance, and it will then be feasible to avoid having to change the wire during the winding of a section, the whole of the central section alone requiring to be wound with the larger wire. In the two kinds of section there will then be, respectively $\frac{2{\cdot}02}{0{\cdot}095} = 21{\cdot}2$ and $\frac{2{\cdot}02}{0{\cdot}100} = 20{\cdot}2$ turns per layer, or more accurately with one turn deducted 20·2 and 19·2 turns. In order to bring the ends of the sections together for soldering and the ends of the bobbin as a whole away from the end flanges, it is with three sections advantageous to have an even number of layers in the upper and lower sections and an uneven number of layers in the central section. The final winding will therefore be arranged with the two end sections each of 28 layers of 0·080", and a depth in each of 2·4". The central section will be given 27 layers of 0·085", with a depth of 2·43". The mean length of a turn will be slightly less than in the preliminary calculation, or, say, l_s = 1·072 yard. In tabular form we thus have—

	No. of Turns.	Yards.	
28 layers of 0·080 . .	566	607	—
27 „ 0·085 . .	518	—	556
28 „ 0·080 . .	566	607	—
Per bobbin . . .	1650	1214	556
In 4 bobbins . .	6600	4858	2224
Ω per 1,000 yards . .	...	4·86	4·32
Resistance . . .	—	23·7	9·7
		33·4 ohms.	

The corrected cooling surface shows so slight a reduction that the temperature will remain practically the same as first calculated, and the difference in the rate at which energy is lost in the central as compared with the outer sections will not be sufficient to demand any further adjustment.

The total resistance of the four bobbins when hot will therefore be 33·4 × 1·16 = 38·8 ohms, and the required ampere-turns will be obtained with an exciting current of 5·75 amperes. The exciting voltage will then be 223·1, which falls within our assumed limit, and the loss of energy in the shunt coils at the rate of 1,280 watts will be 1·6 per cent. of the output, with a total loss in the shunt and rheostat combined at the rate of 1,320 watts, or 1·65 per cent. of the output of 80 kilowatts. The weight of wire will be 283 lb. of 0·080" and 145 lb. of 0·085", or 428 lb. on the whole machine.

§ 9. External characteristic curve of shunt machine.—If a dynamo be run at a constant speed, and the resistance of its external circuit be varied so as to alter the value of the external current, the curve connecting simultaneous values of the terminal voltage, V_t, and the external current, I_t, for a given speed of rotation is known as the *external characteristic* of the machine for that speed; since from it the behaviour of the machine under varying conditions of load can be graphically studied. If a rheostat is employed in conjunction with the field circuit, its resistance is assumed to be maintained constant, as well as the speed. The amperes of such a curve are usually plotted horizontally as abscissae with the corresponding volts as vertical ordinates. The two may either be obtained by direct measurement, voltmeter and ammeter being read off simultaneously, or the curve may be derived from the flux curves of the machine. In the case of a shunt-wound machine the curve of external voltage and current will be found to take the characteristic form shown in Fig. 289, *OLKD*. The manner in which it may be derived from the flux-curves has now to be explained, and first it will be necessary to consider the process by which the three curves of Fig. 274 may be determined by direct experiment on a shunt-wound dynamo.

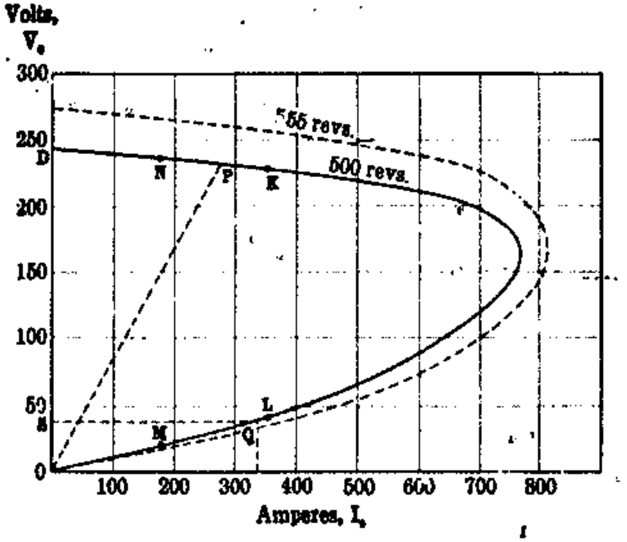

FIG. 289.—Characteristic curve of shunt-wound dynamo.

From equation (44a) it follows that E_a for a constant speed is always proportional to Φ_a, the numerical relation between the two depending upon the nature of the winding and number of active conductors. In a shunt dynamo $I_a = I_s + I_e$; and $E_a = V_b + I_a(R_a + R_b)$, where R_b is the resistance of the brushes; whence $\Phi_a \propto V_b + I_a(R_a + R_b)$. If, therefore, V_b be observed for different excitations, the flux Φ_a can be thence deduced. The ampere-turns on the field-magnet are $AT_s = I_s \times T_s$. $I_s = \frac{V_b}{R_s + R_r}$ may be obtained by measuring the voltage at the brushes and dividing it by the resistance of the shunt and rheostat; but for greater accuracy it is preferable to measure it directly by an ammeter, since the resistance of the shunt is continually altering if the machine is in process of warming up during the tests.

When the external circuit is open, the only current flowing is that through the shunt. As a rule, this is so small that $I_s R_a$ becomes negligible, and V_b and E_a are almost identical. If, therefore, the armature be run at different speeds, and a series of simultaneous readings of the speed, the voltage at the brushes, and the shunt current be taken, a curve can be plotted from the readings which will connect Φ_a and AT_s; the armature ampere-turns due to the shunt current alone being very small, their influence on the field may practically be neglected, and the curve thus obtained is the highest or " no current " curve of flux of Fig. 274. Owing to the small amount of residual magnetism which persists in the machine even when not excited, the flux-curve as thus practically determined does not descend strictly to zero; but towards the origin curves round slightly, and ends a little above zero (cp. Fig. 292); there is further a small difference in the curves according as the readings are taken with the excitation progressively increasing or progressively decreasing. To obtain the lower curves of flux for either " half-current " or " full-current," the same readings must be taken as for the " no-current " curve; but between the readings at each different speed the resistance of the external circuit must be altered, so that when the measurements are made for either curve, the current through the armature ($I_a = I_s + I_e$) has the constant value required. The loss of volts over the resistance of the armature and brushes must now be added to the terminal voltage to obtain E_a.

Since $AT_s = \frac{V_x}{R_s} \times T_s$, the potential difference applied to the terminals of the whole shunt-circuit, or $V_x \frac{R_s + R_r}{R_s}$, is $\propto AT_s$ when R_s and R_r are constant, as is the case when a machine has been running for some time and has attained a steady temperature, and further, when the position of the contact-arm of the shunt rheostat is not altered. If, therefore, we possess the flux curves of Fig. 274, these can be converted into curves connecting armature E.M.F. and exciting voltage (or more strictly $V_x \times \frac{R_s + R_r}{R_s}$, if a rheostat is present in the shunt circuit), when some fixed speed is assumed. The full-line curves of Fig. 290 show the curves of Fig. 274, thus converted on the assumption that in our dynamo the number of armature conductors is 450, the number of shunt-turns 1,650 per bobbin, the total resistance of the 4 bobbins 38·8 ohms, and that the constant speed of rotation is to be 500 revs. per minute. From the design of § 8, the rheostat must be given a resistance of 1·2 ohms at full load, so that the combined resistance of shunt and rheostat is 40 ohms, at which it is to be maintained throughout. The armature

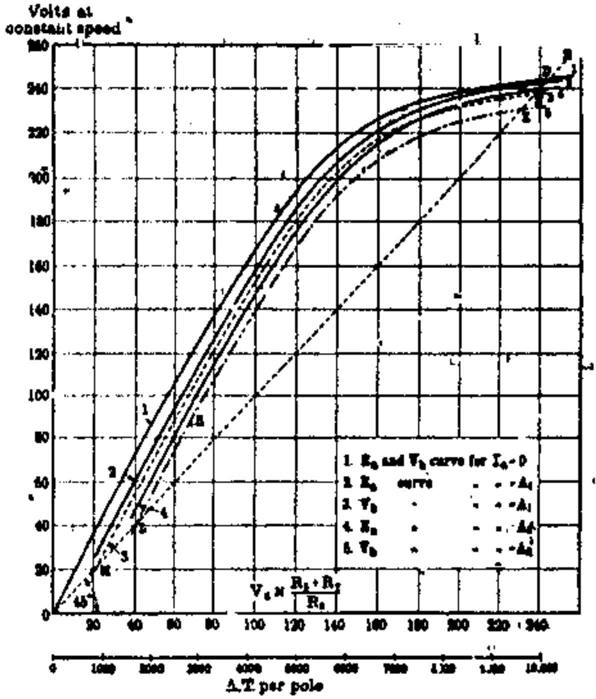

FIG. 290.—Construction for deriving external characteristic of shunt-wound dynamo.

E.M.F. is thus $E_a = \Phi_a \cdot 450 \cdot \frac{500}{60} \times 10^{-8} = \Phi_a \times 37.5 \times 10^{-6}$, and when the exciting voltage on the terminals of the shunt alone is V_s, the corresponding voltage on the terminals of the shunt and rheostat is $V_s \times \frac{R_s + R_r}{R_s} = V_s \cdot \frac{40}{38.8}$. The loss of volts over the armature when warm at half-load is 3, and at full load 6 volts; and to each of these has to be added the loss over the brushes which with hard carbon as their material may be taken as a constant amount = 2 volts. Curve 1 connects E_a or V_b, which has nearly the same value, with $V_x \cdot \frac{R_s + R_r}{R_s}$ when $I_a = 0$. Curve 2 connects E_a and $V_x \cdot \frac{R_s + R_r}{R_s}$ when I_a has the value A_1 ($= 181$ amperes), and curve 4 connects E_a and $V_x \cdot \frac{R_s + R_r}{R_s}$ when $I_a = A_2$ ($= 356$ amperes). From curve 2 is obtained the dotted curve 3, connecting V_b and $V_x \cdot \frac{R_s + R_r}{R_s}$, when $I_a = A_1$ amperes, by deducting from the ordinates of curve 2 the loss of volts over the brushes and armature resistance; the vertical distance between curves 2 and 3 is thus throughout equal to $A_1(R_a + R_b) = 5$ volts. Similarly from curve 4 is derived the chain-dotted curve 5, connecting V_b and $V_x \cdot \frac{R_s + R_r}{R_s}$ when $I_a = A_2$, the vertical distance between the two curves being then 8 volts.

Now, since in a shunt-wound machine V_b is the same as $V_x \cdot \frac{R_s + R_r}{R_s}$, those points on curve 5 (such as L or K) for which the ordinate $V_b =$ the abscissa $V_x \cdot \frac{R_s + R_r}{R_s}$ are the only values of voltage which the machine would give when run at the fixed speed with A_2 amperes flowing through the armature; and in general those points on any curve connecting V_b and $V_x \cdot \frac{R_s + R_r}{R_s}$, for which ordinate and abscissa are equal, give the only possible values of the terminal voltage for the particular armature current. Deducting the shunt current from the total armature current, we obtain the external current; thus at point K, $I_s = \frac{230 \text{ volts}}{40 \text{ ohms}} = 5{\cdot}75$, $I_a =$ nearly 355·75 amperes, and therefore $I_e = 350$ and $V_t = 230$ are simultaneous values of external current and terminal voltage. All such points are necessarily passed through by the straight line OH, which is drawn at an angle of 45° from the axis of abscissae, as *e.g.* K and L, N and M, D and Q; and after deduction for the shunt current these may be plotted as part of the external characteristic, as shown by the corresponding letters in the full-line curve of Fig. 289. As the current is increased, the two points at which the V_b curve intersects the diagonal draw together, and the maximum current is that given by the V_b curve, which is just touched by line OH as a tangent.

§ 10. Deductions from characteristic of shunt dynamo.—It will be seen from Fig. 289 that for the shunt-wound dynamo running at any one fixed speed there is a maximum value for the external current which it can give. Owing to the heat which would be generated in the armature winding by a long-continued passage of this maximum current it may be, and usually is, impossible to work the machine at the point of maximum current; the maximum current, in fact, is usually more than double the working current. Apart, however, from the question of the heat damaging the winding, it is for another reason inadvisable to work close to this point. After rounding the point of maximum current the characteristic curve descends very rapidly, and almost in a straight line to the origin. Thus in the diagram (Fig. 289) the part OQ is practically a straight line, and this implies that for an external resistance $= \frac{QR \text{ volts}}{OR \text{ amperes}}$ the terminal voltage may have any value between zero and OS volts, the external current correspondingly varying between zero and OR amperes; apparently, therefore, the machine might give widely different voltages although running at exactly the same speed on the same external resistance. But in reality the flux of the field is then unstable owing to the voltage on the shunt not being sufficient to magnetize the iron properly; hence if, when working near the point of maximum current, the resistance of the external current becomes lowered to a value below that which corresponds to the maximum current, the machine loses its magnetism altogether, and the voltage runs down to zero. The practical importance of this is that if a shunt-wound machine be accidentally short-circuited when at work, or, in other words, if R_e is reduced almost to $= 0$, the armature winding is not burnt up by the continued passage of an abnormally large current; the machine, on the other hand, becomes demagnetized and gives no current, although the driving engine may be running at a speed higher than the normal.[1] Neither will a shunt-wound machine excite if an external circuit of abnormally low resistance be closed on it, so that it is unharmed if, when running alone, its terminals are short-circuited through an accidental misconnection of its leads. For every value of the external current except the maximum there are two values of the external voltage, and which of the two voltages is obtained depends entirely upon the resistance of the external circuit; this latter is equal to V_e/I_e or the slope of the line to any point, P, on the curve, *i.e.* to the tangent of the angle made by OP with the horizontal axis multiplied by the ratio of the scales to which volts and amperes are plotted, or simply to $\tan a$ when V_e and I_e are plotted to the same scale. The slope of the full-line curve between L and O marks the *critical resistance* of the external circuit for a speed of 500 revolutions per minute; at this value the magnetism is unstable, and at any lower value the machine will fail to excite or maintain its excitation.

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[1] Occasionally a complete short-circuit of a shunt dynamo will, through certain secondary reactions, end in magnetizing its field slightly in the reverse direction, so that, when again self-excited, its polarity is reversed.

For each constant speed the same shunt-wound dynamo gives a different external characteristic. Thus in Fig. 289 the dotted curve shows the external characteristic of the same dynamo at a constant speed of 555 revolutions per minute instead of 500, and it will be seen that at the new speed the maximum current is increased. The higher the speed the less is the slope of the descending branch of the curve; or, in other words, the smaller is the critical resistance which the external circuit may have, without the dynamo losing its magnetism.

§ 11. Instability of magnetism.—Instability of the magnetism requires to be carefully guarded against in the design of self-exciting dynamos. Figs. 289 and 290 show that the unstable portion of the curve between *L* and *O* occurs when the flux falls on the initial straight portions of the curves in Fig. 274, where the ampere-turns over the air-gaps form almost the whole of the excitation; hence if the machine is designed so that the working number of lines falls on the lower part of the flux curve where it descends rapidly towards the origin, the magnetism of the machine as a self-exciting dynamo will be *unstable*. Even if the field hold its magnetism, a very slight variation of the speed will cause a large variation in the voltage—a result which is always undesirable, and especially so if the machine be feeding lamps directly. Thus in the case of a shunt-wound machine, suppose that its speed is raised *slightly*, the increased E.M.F. causes an increase in the current through the shunt, which will again increase the flux and the E.M.F., and the lower down the curve of magnetization that the machine is worked, the greater is the effect of any variation in the shunt current upon the E.M.F., owing to the magnet being less saturated.

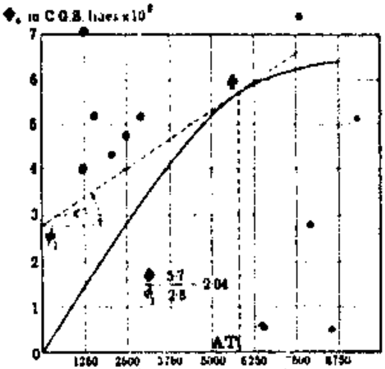

FIG. 291.

A measure of the percentage variation in the voltage which follows from a certain percentage variation in the speed may be obtained by the following construction.[1] Let $O\Phi$ (Fig. 291) be a portion of the flux curve containing the working point corresponding to Φ lines at which it is desired to investigate the effect of change of speed. The same curve with a different scale of ordinates will also represent the voltage, or $E_a = kN\Phi$, where k is a constant converting lines of flux into volts at the speed of N revs. per minute. At the point Φ draw a tangent to the curve; let it cut the vertical axis at ϕ_1, making an angle α with the horizontal. The equation to the tangent line is $\Phi = \phi_1 + X \tan \alpha$; and in the shunt machine the excitation is practically proportional to the armature voltage, or $X = cE_a$, where c is some constant depending upon the field winding. For a very small alteration of the voltage the working point may be taken as moving up or down the tangent, and for a very small alteration of the speed k may be assumed constant. Hence $E_a = kN(\phi_1 + cE_a \tan \alpha)$. Differentiating with respect to the speed, the rate of change of the voltage when the speed begins to alter is

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[1] Cp. Poynder and Wimperis, *Engineering*, 3rd May, 1901.

$$\frac{dE_a}{dN} = k\left\{\phi_1 + c\left(N\frac{dE_a}{dN} + E_a\right)\tan \alpha\right\}$$

whence $$\frac{dE_a}{dN}\left(1 - kcN \tan \alpha\right) = k(\phi_1 + cE_a \tan \alpha) = k\Phi$$

Since $\Phi = \phi_1 + kcN\Phi \tan \alpha$, we have $\Phi(1 - kcN \tan \alpha) = \phi_1$

or $$(1 - kcN \tan \alpha) = \frac{\phi_1}{\Phi}$$

therefore $$\frac{dE_a}{dN} = k\frac{\Phi^2}{\phi_1}$$

Multiplying both sides by $\frac{N}{E_a}$, and substituting $kN\Phi$ for E_a on the right-hand side,

$$\frac{dE_a}{dN} \times \frac{N}{E_a} = \frac{1}{\Phi} \cdot \frac{\Phi^2}{\phi_1}$$

or $$\frac{\frac{dE_a}{E_a}}{\frac{dN}{N}} = \frac{\text{fractional change of voltage}}{\text{fractional change of speed}} = \frac{\Phi}{\phi_1} \qquad (138)$$

The percentage change of the voltage corresponding to a given percentage change of the speed is thus directly given by the ratio Φ/ϕ_1, and this must not be allowed to exceed a certain limiting value if instability of the voltage is to be avoided. It can only be unity if the machine is separately excited. Fig. 291 illustrates the case of the 21″ × 11″ dynamo which has been above considered when giving 220 volts on open circuit at a no-load speed of 515 revolutions per minute; the flux required is then $\Phi_a = \frac{220 \times 60 \times 10^8}{450 \times 515} =$

$5{\cdot}7 \times 10^6$ C.G.S. lines, and it has been designed to work on a fairly stable part of the curve so as to be satisfactory under these conditions which would have to be met in practice. The ratio $\Phi/\phi_1 = 2{\cdot}04$, and a 1 per cent. variation of the speed implies a 2·04 per cent. variation of the voltage. As the working point approaches the origin, the ratio Φ/ϕ_1 rises, and in practice, in order to avoid instability, should not exceed 3, so that the change of the voltage becomes 3 per cent. for a 1 per cent. variation of speed.[1] As will be explained later, it is especially in over-compounded dynamos that the safe limit is likely to be approached in regard to the open-circuit voltage given by the shunt winding. As a matter of fact, the change of voltage for any change of speed is to a certain extent held in check by the hysteresis, which assists in maintaining the stability of the magnetism; but the determination of the ratio Φ/ϕ_1 affords a very useful warning to the designer when in doubt as to the lowest point on the flux-curve at which it is safe to work.

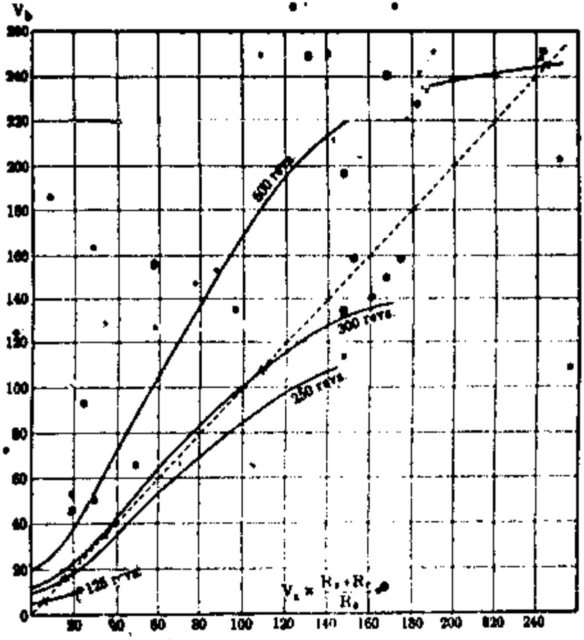

FIG. 292.

A further disastrous consequence of designing a shunt-wound machine to work on the initial straight portion of the flux-curve that, even when the external circuit is open and the machine is ru very nearly at the normal speed for which it is designed, it may b difficult to reach the proper excitation. When the flux curve i converted into a voltage curve, the diagonal must not fall too nea its initial part. As already stated, the no-current flux-curve owing to the presence of residual magnetism, really ends at som point on the vertical axis slightly above the origin. If now a number of voltage curves similar to those of Fig. 290 are plotted for several speeds, the points at which they cut the diagonal (Fig. 292) give the voltages for the different speeds, and these when plotted as in Fig. 293 show that there is a *crucial speed* at which the voltage rapidly rises. Below this the effect is almost entirely due to the residual magnetism, and as in practice this is very small it has been exaggerated in the diagram in order to render the matter clearer. If the dynamo is run up to its full speed before the circuit of the shunt is closed, then on closing the latter (and neglecting the secondary effects from self-induction) the rising voltage follows the upper curve of Fig. 292; the voltage at the brushes is initially higher than that corresponding to the required excitation, and up to a certain point the surplus ampere-turns continue to increase, after which they decrease until a condition of stable equilibrium is reached at P. If the dynamo is run up to full speed with the shunt closed, the voltage follows the diagonal line, and a rapid increase is obtained when the speed reaches the crucial value which in our 21″ × 11″ dynamo as a shunt-wound machine is about 270 revolutions per minute. This crucial speed is determined by the air-line, and is easily calculated from the flux-curve as follows.

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[1] Cp. Boucherot (*Trans. Intern. Elect. Congress, St. Louis 1904*, Vol. 1, p. 669), who calls the ratio $\frac{dE}{E} \Big/ \frac{dN}{N}$ the kinetic variation of voltage, and recommends that its value should be limited to 2.

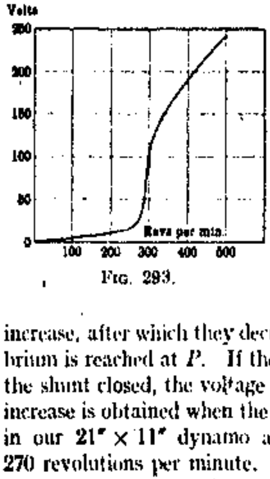

FIG. 293.

In the shunt machine the ampere-turns are themselves dependent upon the voltage at the brushes which is nearly proportional to the flux at any given speed. Hence $AT_s \propto$ flux × speed, or speed $\propto \frac{AT_s}{\text{flux}}$. In Fig. 294, if Φ be the working point at no-load with the designed speed N_1, $N_1 \propto \frac{AT_s}{\Phi}$. At the crucial speed N_0 the ampere-turns are practically proportional to the air-gap reluctance, and the ratio of the two is given by any point on the air-line, and therefore by point ϕ_2. Hence $N_0 \propto \frac{AT_s}{\phi_2}$ and $\frac{N_0}{N} = \frac{\Phi}{\phi_2}$. In our case from the characteristic curve of Fig. 287 the open-circuit E.M.F. at 500 revolutions per minute is 245 volts, corresponding to $\Phi_a = 6{\cdot}54 \times 10^6$, so that, as shown in Fig. 294, $\frac{N_0}{N_1} = \frac{6{\cdot}54}{12{\cdot}1} = 0{\cdot}54$. In other words, the crucial speed $N_0 = N_1 \cdot \frac{\Phi}{\Phi_1}$ is approximately $500 \times 0{\cdot}54 = 270$ revolutions per minute.

The crucial speed is, in fact, immediately definable from the constructional data of the machine as follows. On open external

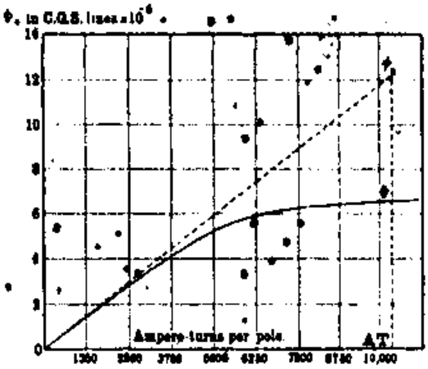

FIG. 294.

circuit at the normal speed the armature induced E.M.F. is $E_a = I_s(R_a + R_s + R_r)$, and is also $\frac{p}{a} \times \Phi_a \times Z \times \frac{N}{60} \times 10^{-8}$, whence $\Phi_a N_1 = \frac{I_s(R_a + R_s + R_r) \times 60 \times 10^8}{Z} \times \frac{p}{a}$. The M.M.F. required over the single air-gap of one magnetic circuit is equal to the product of flux × air-gap reluctance, the latter being $\frac{Kl_g}{a_g}$, so that the ampere-turns of air-gap excitation are equal to the flux $\times \frac{K \cdot l_g}{1{\cdot}257a_g}$. Hence for the particular flux ϕ_s they are $0{\cdot}8\,Kl_g \cdot \frac{\phi_s}{a_g}$, and this is also equal to I_sT_s, where T_s is the number of shunt-turns in a bobbin corresponding to one pole. The crucial speed is thus

$$N_0 = \frac{0{\cdot}8\,K \cdot l_g(R_a + R_s + R_r) \times 60 \times 10^8}{a_g \cdot T_s \cdot Z} \times \frac{p}{a}$$

In our case $p = a$, and $R_a + R_s + R_r = 0{\cdot}02 + 38{\cdot}8 + 1{\cdot}2 = 40{\cdot}02$ ohms, and $T_s = 1{,}650$; as in Chapter XVI, § 9, the constant by which the flux must be multiplied in order to give the ampere turns of air-gap excitation is $\frac{0{\cdot}8\,K\,.\,l_g}{a_g} = \frac{0{\cdot}8 \times 1{\cdot}09 \times 0{\cdot}798}{838}$ $= 0{\cdot}00083$, and

$$N_0 = \frac{83{,}000 \times 40{\cdot}02 \times 60}{450 \times 1{,}650} = 270 \text{ revolutions per minute.}$$

It is evident from Fig. 292 that the crucial speed is that for which the curve of V_t in relation to $V_a \,.\, \frac{R_s + R_r}{R_s}$ (assuming that there is no residual magnetism and that the no-current flux curve descended strictly to the origin) would be a tangent to the diagonal at the origin. For self-excitation to commence there must be some residual magnetism, but in order to reach the true self-excitation that is required the condition $N_1 > N_0$ must hold. Failure to excite in this sense is seldom to be feared in practice with any but very small machines, except in the case of electroplating and similar dynamos of very low voltage. Yet even if self-excitation takes place it is always important, as has been already emphasized, to avoid instability of the magnetism and to design the machine so that it attains a definite and high degree of magnetism when self-exciting on the shunt winding. It must therefore be worked fairly high up on the curves of flux, and in Fig. 274 the best portions whereon to work fall within the horizontal lines marking 5½ and 6½ million lines respectively. These portions may be said to lie on the bend or knee of the curve, but it must be remembered that the apparent position of this bend depends largely on the relative scale to which lines and ampere-turns are plotted. Another advantage of working high up the curve is that the difference of the ampere-turns of the shunt when hot and when cold then produces but small effect upon the flux and E.M.F. of the machine, since the magnet is well saturated. Also, the vertical distance between the no-current and full-current curves decreases as the total flux is increased, so that the variation in the voltage of the machine between full-load and no-load is small when the magnet is strongly excited. If, however, the working flux-density be taken too high, a large amount of copper will be required on the field, and if for any reason the actual curve comes below the predetermined curve, it may be practically impossible to rewind the magnet so as to obtain a greater flux, so that care must also be exercised not to exceed the due limit in this direction.[1]

§ 12. Fall of volts in shunt-wound dynamo, and its regulation.—It will already be apparent that much information can be obtained from the shape of the characteristic curve of the dynamo; in the

[1] Cp. Miles Walker, *The Diagnosing of Troubles in Electrical Machines*, pp. 248 and 293.

case of a shunt-wound dynamo run at a constant speed, we see that its E.M.F. is highest when the external circuit is open, and the only current flowing is that through the shunt. When the external circuit is closed, and the armature current is swelled by the addition of an external current, not only does the loss of volts over the resistance of the armature progressively increase as the armature current increases, but the demagnetizing effect of any back armature ampere-turns increases. Hence not only does the exciting voltage at the brushes of the dynamo fall, but the flux due to a given number of shunt ampere-turns is decreased. Owing, therefore, to the combined effect of the two causes, namely, the increase of any back ampere-turns, AT_b, and the loss of volts over $R_a + R_b$, the characteristic gradually falls throughout the entire working range of the dynamo. If, however, the armature be of low resistance, the drop in volts for any current within the working range will be but small, and consequently the shunt-wound dynamo may in such cases be practically regarded as giving a nearly constant voltage when run at a constant speed.

The shunt-wound dynamo of Fig. 289 has been above designed to work high up on the flux-curve of a well saturated field-magnet, so that it affords a good example of the regulation which may be obtained under favourable conditions with simple shunt winding.[1] By "regulation" in the present connection is understood the degree in which under different loads the machine approximates to a constant voltage at the terminals when run at its normal speed and without alteration of the rheostat inserted in the shunt-circuit; *i.e.* it is the rise of volts when the full load is switched off expressed as a percentage of the full-load volts. From Fig. 289 it is seen that if the rheostat resistance is adjusted to give 230 terminal volts at full-load and at the normal speed of 500 revolutions per minute, the switching off of the full-load with the speed maintained constant will cause the volts to rise to 245—an increase of 6½ per cent. In practice this rise of volts is magnified by the difference between the no-load and full-load speeds as fixed by the governor of the prime mover. When a dynamo is driven by an engine and forms the whole or a considerable portion of the load on the engine, the greater the output the slower will be the speed of the engine, even though it is governed for an approximately constant speed. This difference of speed between full- and no-load in an ordinary engine varies, but usually ranges with a good governor from 3 to 4 per cent. of the no-load speed. Its effect is cumulative, since not only does removal of the full load cause the E.M.F. to rise for the same flux, but the excitation is thereby increased, which again causes a further rise of volts. Since any such rise of volts is detrimental to the good working of a central station or other installation of motors and lamps, the shunt machine is almost invariably supplied with a rheostat of sufficient range to enable the terminal volts not only to be kept constant but even to be reduced at light loads. The least favourable conditions requiring the highest resistance in the rheostat will occur when the machine is working at no-load and before it has become in any way heated by prolonged running. Thus in the case of the 21" × 11" dynamo above considered the necessary resistance which the rheostat must provide is to be calculated as follows. On the assumption that it is to give the reduced voltage of 220 at no-load, at a speed of 515 revolutions per minute, or 3 per cent. above the full-load speed to allow for the governor range, a flux of $5{\cdot}7 \times 10^6$ lines per magnetic circuit will suffice, and from Fig. 274 this is obtained with 5,800 ampere-turns per pole, or with a shunt current of 3·42 amperes. The resistance of the shunt when cold being 32·76 ohms, $I_s(R_s + R_r) = 3{\cdot}42\,(32{\cdot}76 + R_r) = 220$, whence $R_r = 31{\cdot}74$, say 32 ohms, which will be divided up between a number of intermediate steps proportionate to the degree of fineness which is required in the regulation, and with a current-carrying capacity tapering approximately from 6 to 3·4 amperes.

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[1] Cp. Miles Walker, *loc. cit.*, pp. 248 268.

While the rise of volts on switching the full load off varies in a shunt-wound machine from 7 to 20 per cent., it is evident that the fall of volts on switching the full-load on is with the same initial volts in the two cases considerably greater. Indeed, it may result in the machine becoming almost demagnetized, owing to the resistance of the shunt circuit with its rheostat fully inserted bearing a high ratio to the resistance of the external circuit, and owing to the loss of volts over the armature resistance and brushes with the full current.

§ 13. Uses of shunt-wound dynamos.—Large continuous-current dynamos for central-station work, which supply current at 220 or 550 volts to a network of mains, are often shunt-wound. The voltage at the station end of the feeders to the network is in such cases conveniently regulated by means of rheostats. For the direct lighting of incandescent lamps in smaller installations, shunt-wound dynamos are not so suitable, owing to the necessity for constant attendance in order to regulate their E.M.F. according to the load, if a constant voltage is to be maintained on the lamps. They are, however, frequently used in conjunction with accumulators, and in such cases, by means of a supplementary resistance in the shunt, they are arranged to charge accumulators during the day up to about 130 volts, and at night to work in parallel with the battery, lighting incandescent lamps at 100 volts, the speed under the two conditions being maintained at nearly the same value.

For the electro-deposition of metals, shunt-wound dynamos are employed; for a single electrolytic bath with its leads only some four or five volts are required, but several baths are commonly worked in series at a correspondingly higher voltage. For charging accumulators, and for electrolytic or electrometallurgical work, shunt-winding is alone suitable; if the voltage of the dynamo becomes less than the E.M.F. of the cells, or the current through the electrolytic baths becomes reversed through polarization at their electrodes, the direction of the current round the shunt remains unchanged, although the current through the armature will be reversed. The result is that the machine runs as a motor in the same direction as it did when acting as a generator, and therefore opposes a back E.M.F. to the discharge from the cells; this back E.M.F. prevents the flow of a large current which might burn up the armature and also injure the cells.

At high voltages the necessary diameter of wire for a shunt-winding on a small machine becomes very small, and fine wire is not only expensive in itself, but the time and trouble of winding the great length of it which is required become very considerable. Hence the maximum voltage for a small machine which has all or most of its excitation provided by a shunt-circuit may be set at about 500 volts, but in large generators of, say, 400 kilowatts output this may be raised to 2,250 volts.

§ 14. Determination of series winding.—Series-winding, although common in motors, is but seldom met with in dynamos; yet for purposes of comparison with shunt-winding it will be instructive to work out the details of a series winding, its necessary size of wire and its disposition, especially as many of the practical considerations thereby brought to light will be found equally applicable to the compound-wound dynamo that has later to be discussed.

Assuming, then, that it is desired to convert our 21" × 11" dynamo into a series-wound machine without alteration of the armature, and that the terminal voltage is still to remain 230 at full load, an addition must be made to the armature induced E.M.F. in order to cover the loss of volts over the series winding. With the same dimensions of pole as in § 8, we know that a suitable depth of coil and satisfactory heating conditions will be attained if we allow a loss of about 1,280 watts over the field-winding. The full armature current now becomes available externally, but as this differs so slightly from 350 amperes the latter figure will be again taken, so that the external volts and amperes forming the output will remain unaltered. The voltage expended over the series-winding must therefore not exceed $\frac{1{,}280 \text{ watts}}{350 \text{ amperes}}$ = 3·65 volts, or 1·6 per cent. of the terminal volts. When this is added to the loss of 5·9 volts over the armature resistance and the constant loss of about 2 volts over the brushes, E_a must now be 241·55, and at the same full load speed of 500 revolutions per minute the required flux will be $\Phi_a = \frac{241{\cdot}55 \times 60 \times 10^8}{460 \times 500} = 6{\cdot}3 \times 10^6$, which will from Fig. 274 necessitate 10,200 ampere-turns per pole.

Assuming all the 4 bobbins to be connected in series, and the same surface rise of temperature, the required area of wire is therefore by equation (125)

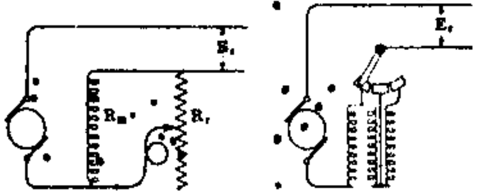
$$\frac{0.02445 \times 10{,}200 \times 4 \times 1{\cdot}08 \times 1{\cdot}16}{3{\cdot}65 \times 1{,}000} = 0{\cdot}344 \text{ square inch,}$$

and the number of turns per coil is $T_m = \frac{AT_f}{I_s} = \frac{10{,}200}{350} = 29\frac{1}{4}$. A single round wire of the necessary diameter to give this section is out of the question owing to the difficulty of winding it. A number of alternatives are, however, possible. Thus in a 4-pole machine two of the 4 bobbins may be placed in parallel and the pair in series with the remaining pair; the current in any turn will then be halved, and the number of turns doubled, but the section of each wire need be only half as large. Or all the bobbins could be placed in parallel, when the current in each, being again halved, becomes $\frac{350}{4} = 87{\cdot}5$ amperes. There are, however, two objections to any parallel connection of the bobbins, and these become of increasing importance as the number of parallel paths is increased. In the first place, as the size of each wire is reduced, the ratio of the copper area to the space occupied or the value of σ diminishes, so that it may finally become impossible to find room for the necessary volume of copper. In the second place, owing to the different location of the several bobbins on the machine they may be differently affected as regards the effectiveness of their cooling surface, so that even if their resistances are exactly equal when cold, they differ when hot; the total current then becomes unequally divided between them, and one or more magnetic circuits may have a greater number of ampere-turns than the remainder—a result which is especially disadvantageous with lap-wound armatures. For both reasons, therefore, it is advisable to adhere to the arrangement of all the bobbins in series.

Returning, then, to the series connection, a rectangular strip may be tried, double-cotton-covered and wound on flat-wise. Six layers of 4·9 turns per layer will give the required number of turns per pole; the thickness of the insulated strip must not exceed $\frac{2{\cdot}5''}{6}$, say 0·4″, and the thickness of the bare copper will be 0·4 − 0·025 = 0·375″. The width must therefore be 0·915″, or when insulated 0·94″. In calculating the required winding length, especially with a wide strip, one turn must always be added to the actual number which each layer is to give, since the space lost from the spiral way in which the strip must be wound amounts to the width of one turn; hence in our case (number of turns + 1) (width of insulated wire) = (4·9 + 1) × 0·94 = 5·55″. Or *vice versâ*, in calculating the number of turns per layer that can be wound within a certain length one turn must be deducted from the quotient $\frac{\text{winding length}}{\text{width of insulated wire}}$. If the strip be wide and the length of coil be short, this loss of space amounts to an appreciable percentage of the total length. For this reason the proposed use of rectangular strip wound flatwise, although it has in itself a very high value for σ, does not lend itself conveniently to a subdivision of the bobbin into the three sections with air-gaps between them which is required in order to secure the best results on the score of ventilation. Further, the copper even when divided into two strips each 0·1875″ thick, wound in parallel, will be troublesome to wind. An equivalent section of copper wound on edge, say 2·45″ × 0·14″, reduces the above-mentioned loss of space very considerably; the winding length, in order to give 29½ turns per pole, must now correspond to 30 turns, or if the neighbouring turns are insulated with strips of calico to a thickness of 0·160″, the length must be 30 × 0·16 = 4·8″. Whether a quarter turn can be secured depends upon where the wire is led on to or off the bobbins, and a half-turn is usually more convenient as bringing the ends to the opposite sides of each bobbin and in line all round the circle of the poles in a convenient position for connecting together. In spite of the lower value of σ the edgewise arrangement requires less space and is the best. But the winding of a wide strip on edge calls for special tools and skill in manipulation, so that as an alternative a thin wide strip wound on the flat may be tried. The thickness of the strip will be $\frac{2{\cdot}5''}{30} = 0{\cdot}083''$ when insulated with calico strips pasted to one side, or say 0·060″ bare. The necessary width is then 5·75″, and this may be conveniently divided into three sections each 1·9″ wide. The sections of each bobbin are coupled together into parallel where the connections are made to the neighbouring coils by which the several bobbins are put in series.

Finally, therefore, each pole will be wound with three sections, each containing 29½ turns of a copper strip 1·9" wide × 0·060" thick, insulated to 0·080". The joint area of the three strips is 1·9 × 3 × 0·06 = 0·342 square inch, and their joint resistance per 1,000 yards is $\frac{0 \cdot 02445}{0 \cdot 342} = 0 \cdot 0716$ ohm. The resistance of the 4 bobbins in series is $\frac{29 \cdot 5 \times 1 \cdot 08 \times 4}{1{,}000} \times 0 \cdot 0716 = 0 \cdot 00915$ when cold, or 0·00915 × 1·16 = 0·0106 ohm when hot. The loss of volts is 0·0106 × 350 = 3·71, and of watts is 1,298. Our original allowance for the armature E.M.F., etc., may therefore be permitted to stand. The weight of wire is 11·55 × 0·342 × 128 = 506 lb. It will thus be seen that, in spite of the greater number of ampere-turns which are required on the field for the series machine to give the same terminal volts as the shunt-wound machine, the better utilization of the space which results from the use of strip as compared with round wire enables the same size of bobbins to be retained, the weight of copper contained therein being greater.

Owing to the higher value of σ with rectangular strip copper as compared with round wire, and in general owing to the fewer turns of comparatively large area, the current-density in series winding is usually lower than in shunt coils, since the watts per cubic inch of total space should be the same for coils of similar dimensions. If, as usual in continuous-current dynamos, the field-magnet is stationary, the current-density in the series winding seldom exceeds 1,000 amperes per square inch, and on an average ranges from 750 to 800 amperes per square inch.



(a) (b)

FIG. 295.—Regulation of series-wound dynamo.

Regulation of the series machine is effected either (*a*) by a *diverter*, or less frequently (*b*) by alteration of the number of turns through which the external current passes (Fig. 295). In the latter case the series winding is divided into a number of sections from the ends of which leads are brought out to the contacts of a regulating switch; by moving the lever of the latter the groups of sections are brought into action or cut out one after the other. This method is, however, seldom employed, since it can only be adapted to give a few large steps with consequent sparking at the contacts.

A more gradual change can be obtained with a diverter (Fig. 295*a*); this latter consists of an adjustable resistance connected in parallel with the series winding. By moving the arm of the regulating switch over the contacts connected to the resistance, the amount which is in parallel with the series winding is gradually altered; thus by decrease of the ohms of the resistance a gradually increasing proportion of the total current is diverted away from the series coils, and the field is correspondingly weakened.

§ 15. External characteristic of series-wound dynamo.—The external characteristic of the dynamo when series-wound as described in § 14 for a speed of 500 revolutions per minute, is shown in Fig. 296. It may be derived from the flux-curves of Fig. 274 in the following manner. Taking any current, I_1, multiply it by T_{se}, the number of turns per pole in the series-winding, and then find on the flux-curve for the particular current I_1 the Φ_a corresponding to the exciting power, $I_1 T_{se}$. Thence $E_a = \frac{p}{a} \frac{\Phi_a \times Z \times N}{60 \times 10^8}$ can be determined; the loss of volts over the resistance of the armature, brushes, and series-winding = $I_1 \times (R_a + R_b + R_m)$, so that V_e corresponding to a value of $I_e = I_1$ is $E_{g1} - I_1 (R_a + R_b + R_m)$, and the corresponding point on the external characteristic can be plotted. Next, take another value for I_e, and in the same way find the corresponding value of V_e, and so on until sufficient points have been obtained to draw in the curve. If only three or four flux-curves are to hand it will be necessary to interpolate or add other curves in order to determine the characteristic throughout

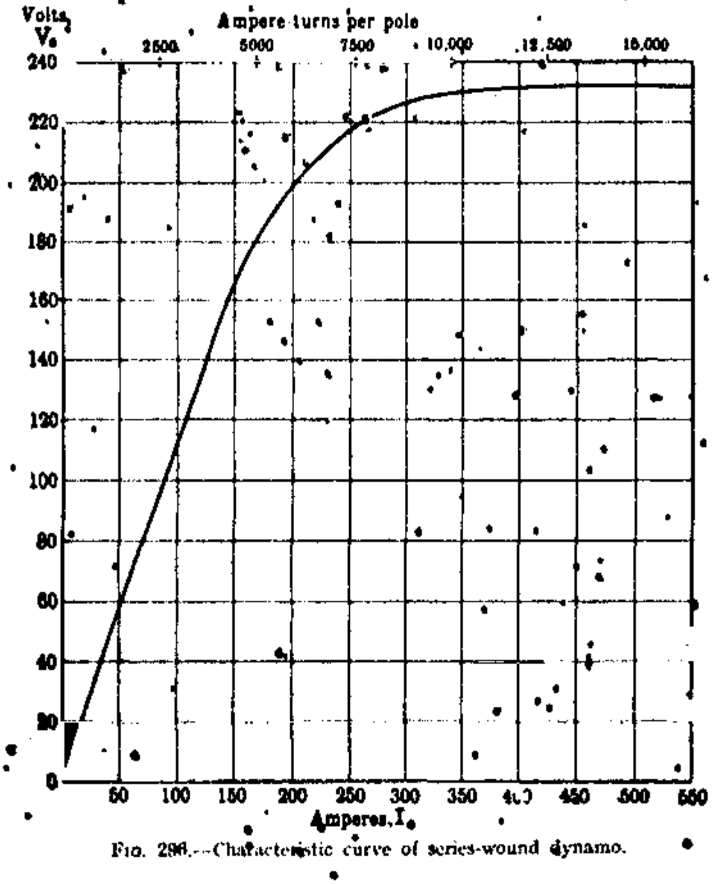


FIG. 296.—Characteristic curve of series-wound dynamo.

a large range of current. Thus the curve for ¾ths of full current will fall approximately midway between the curves for half and full current, but slightly nearer to the former; the back ampere-turns of the armature are less at three-quarters than at full-load, owing to the decreased current, and the proportion of leakage is thereby decreased.

The shape of the external characteristic for a series-wound dynamo is widely different from that for a shunt machine. Since the external current is also the magnetizing current, it resembles in the main a curve of flux. But if the external current can be progressively raised by lowering the resistance, a point is always finally reached at which the terminal voltage decreases as the external current is increased, although this point is usually well beyond the working range of current. The fall of the external characteristic is due to the loss of volts over the resistance of the armature and series winding, and to the demagnetizing effect of any back ampere-turns on the armature. The former loss is directly proportional to the current, while the effect of the back ampere-turns increases faster than the current. On the other hand, when the magnet is approaching saturation, if the external current is increased, the increase in the total flux is by no means proportional to the increase in the exciting power of the field ampere-turns. Hence the induced E.M.F. rises less and less rapidly as the current is increased, and after a certain point the increase in the induced E.M.F. does not so much as compensate for the increased loss of volts over the resistances of the machine; the external characteristic curve therefore attains a maximum height, and thence bends gradually downwards.

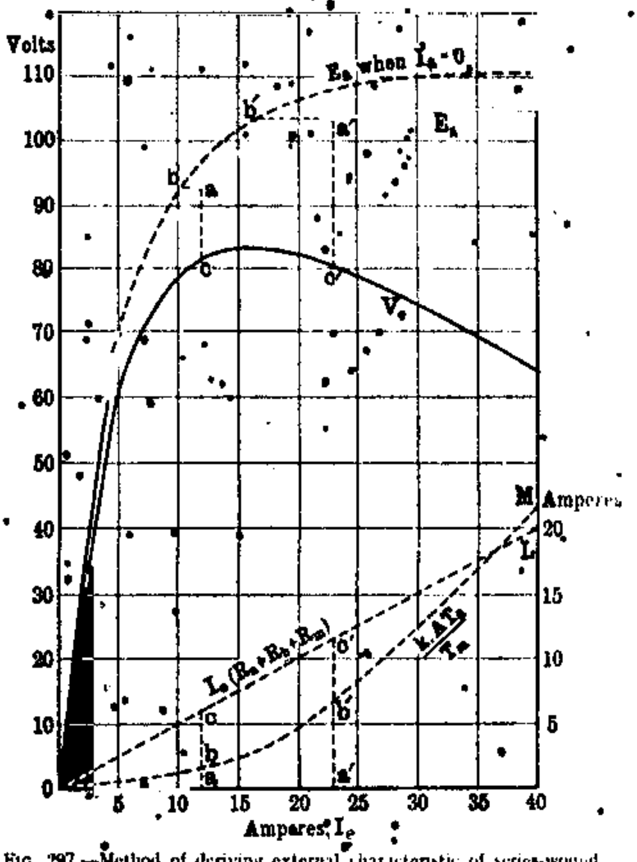


FIG. 297.—Method of deriving external characteristic of series-wound dynamo.

If the brushes have a fixed position the descent is very gradual, as in the case of the small series-wound dynamo illustrated in Fig. 297, which also shows how the external characteristic for a series-wound dynamo may be graphically constructed. The open-circuit flux-curve of the dynamo is first converted into an E.M.F. curve for the given constant speed, as shown by the upper dotted curve in Fig. 297. For any particular value of the current the ampere-turns required to balance all the effects of armature reaction, including the increased leakage, may be expressed as $k.AT_a$ where k increases as saturation is approached; this again may be expressed by the equivalent number of amperes which with the given value of the field turns T_m per pair of poles yield $k.AT_a$, i.e. $\frac{k.AT_a}{T_m}$. The dotted curve marked $\frac{k.AT_a}{T_m}$ is thus drawn, of which the scale in amperes to the right of the diagram is equal to the horizontal scale of abscissae. Inclined to the horizontal is then drawn the line OL, which to the volt scale at the left hand of the diagram measures the loss of volts over the resistances of the armature, brushes, and series coils for any particular current. The induced E.M.F. of the armature for any value of the current is then derived by finding a series of points such that their horizontal distance from the upper dotted curve is equal to the corresponding ordinate ab of the curve OM, and at the same time such that they fall on the vertical from the particular value of the current in question. From the curve of the armature E.M.F. E_a so derived has then to be deducted the loss of volts AC corresponding to each value of the current. If the brushes are given a greater angle of lead as the current is increased, the back ampere-turns of the armature then rise faster than the field ampere turns, and gradually overpower the latter, so that the actual flux may diminish. The curve of the armature E.M.F. then begins itself to bend over, and the descent of the curve of the external voltage is rendered much steeper.

The external characteristic at any other speed is obtained by simply altering the height of the ordinates; the slide rule is set up for the ratio of the speeds, and the calculated values of E_a are altered in proportion to the alteration of the constant speed.

§ 16. Uses of series-wound dynamos.—Series-wound dynamos have been chiefly used for the electric transmission of energy over considerable distances, when one or more generators are employed to supply current to similar series-wound motors through a single series circuit (Chap. XXIII, § 2); and also for high-potential arc lighting.

For running a number of arcs in series since a nearly constant current is required, the drooping external characteristic is a distinct advantage, and on this account the series-wound machine is worked on the descending portion of the curve. If the resistance of any one or more lamps be decreased owing to the carbons being fed together, or if a lamp be entirely cut out of circuit, the momentary increase in the external current is then accompanied by a decrease in the terminal volts; this helps to bring the current back to its normal strength, and although it cannot be sufficient to make the machine entirely self-regulating for constant current at varying potentials, it tends in the right direction, and leaves less for the automatic constant-current regulator to do. Thus in the constant-current dynamos as formerly used for arc lighting the drooping characteristic was expressly exaggerated.

§ 17. Compound winding.—In the case of a shunt-wound dynamo with armature of low resistance its terminal voltage, although approximately constant over a considerable range of current, necessarily falls. A constant voltage over the full range of a dynamo's capacity or even a voltage rising with the load is, however, essential for most purposes, and this requirement can be closely fulfilled by the *compound-wound* dynamo (Fig. 298). If a dynamo be shunt-wound to give a certain voltage at no-load, and the magnet be in addition wound with a certain number of turns connected in series with the external circuit, then, as the load is increased, the current flowing through the series, or as they are also sometimes called "main," turns, will progressively increase the excitation. Now this increase in the excitation may be made not only to balance any increase of the back ampere-turns, as more load is thrown on, but also to increase the total flux through the armature. As a consequence the induced E.M.F. is increased, and when properly proportioned this increase may be made to exceed the loss of voltage over the series-turns sufficiently to compensate for the increased loss of volts over the armature resistance and brushes. Thus while the armature E.M.F. rises with the load, the terminal voltage remains practically constant, however the current be varied over a very considerable range. The external characteristic is therefore practically a straight line throughout the entire working range of current. In the compound-wound dynamo the shunt may, in fact, be regarded as providing a certain initial flux and voltage;

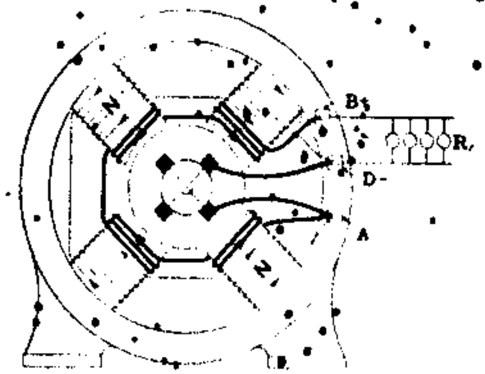
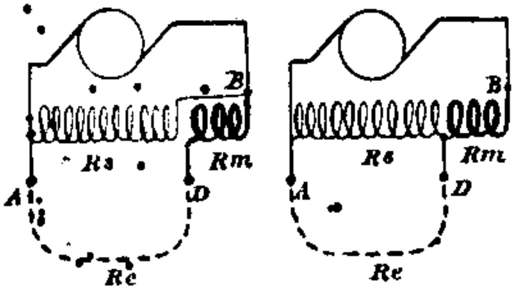


FIG. 298.—Compound-wound dynamo.



Short Shunt. *Long Shunt.*

FIG. 299.

these latter are maintained and reinforced against the combine causes which tend to reduce them by means of the series-turns the exciting power of which varies directly with the external current

The connections of a compound-wound dynamo may be arrange in two slightly different ways, shown diagrammatically in Fig. 299 By the first, which is also shown in Fig. 298, and is known as th "short-shunt" method, the shunt is placed across the brushes o the machine, and the voltage acting on it is $V_b = V_t + I_eR_m$ the current flowing through the series winding being simply th external current I_e. By the second, or "long-shunt" method, th shunt is placed across the terminals of the external circuit; th voltage acting on it is then V_t, while the whole armature curren $I_a = I_e + I_s$ flows through the series winding. Of the two method the first is the more common, but their practical difference is no very important.

As regards the winding of the two sets of magnetizing coil on the magnet bobbins, the series may be wound over the shunt or *vice versâ*, but it is more convenient that they should form separate coils. In the latter case, however, care must be taken that the equality of the turns on each pole is such as to suit the necessitie of the armature winding. Thus in the multipolar machine th series-winding may be confined to alternate poles if the armature b wave-connected, but if it be lap-wound all the poles are preferably similarly wound, each with its proportion of shunt and series-turns.

§ 18. Over-compounding.—A constant speed and a required constant voltage have been tacitly assumed above for the compound-wound dynamo; but such are not in strictness the ordinary conditions of working, owing to the drop in speed between no-load and full-load which results from the governor range, and which averages from 3 to 4 per cent. of the no-load speed. Apart from this mechanical lowering of the speed, there is also the electrical loss of volts over the main leads between the dynamo and the load, which increases in direct proportion to the current passing. If, therefore, a constant potential is required at the far end of the line (as, for example, in a factory with 220-volt incandescent lamps or motors run directly from a dynamo some distance away) the dynamo must give a terminal voltage of, say, 230 volts when supplying full current in order to allow for the loss of potential over the leads. When, however, the load is very light, the dynamo must give little more than 220 volts, and for any external current between zero and the maximum the external voltage should rise in proportion from 220 to 230. Hence in such a case the compound-wound dynamo must give a higher voltage at full-load than at light loads, and that at a lower speed. The desired external characteristic is thus a straight line, not horizontal, but slightly inclined upwards, or, as it is termed, the dynamo is to be *over-compounded*.

§ 19. Example of calculation of compound winding.—Let us suppose that the 21″ × 11″ dynamo of Chapter XVI, §9, has to be compounded to fulfil the following conditions: at 500 revolutions per minute, $V_e = 230$ volts when $I_e = 350$ amperes, and at 515 revolutions $V_e = 220$ when $I_e = 0$, *i.e.* the voltage is to rise by 10 volts while the speed drops about 3 per cent. as the load is increased from no-current to full-current.

To give the required voltage at no-load, Φ_0 must, as in § 11, be $5{\cdot}7 \times 10^6$, and from the no-current curve of Fig. 274 we see that the shunt-winding must then give $AT_{s1} = 5{,}800$ ampere-turns. At full load, allowing a loss of 8 volts over the armature and brush resistances (as before), and of 1 volt over the series-winding, the induced E.M.F. must be 239 volts; the total number of useful lines to give this E.M.F. is $6{\cdot}38 \times 10^6$, and, as calculated in Chapter XVI, § 9, the excitation required per pole to give this flux is $AT_f = 9{,}750$ ampere-turns. At full load the exciting voltage on the shunt is 231, if the machine has a "short-shunt" winding, and the ampere turns due to the shunt are then

$$AT_{s2} = AT_{s1} \times \frac{V_{s2}}{V_{s1}} = 5{,}800 \times \frac{231}{220} = 6{,}090$$

The ampere-turns which the series-winding must produce at full-load are therefore $AT_f - AT_{s2} = 9{,}750 - 6{,}090 = 3{,}660$, and the number of series turns is $T_m = \frac{AT_m}{I_e} = \frac{3{,}660}{350} = 10\tfrac{1}{2}$ per pole.

Assuming a total loss of about 1,280 watts in the field, and a depth of winding of 2·5 inches as in the previous case of the shunt machine, we have still to settle the question of how to divide the total winding space between the shunt and series coils so as to obtain the best results.

The shunt and series coils will be arranged as shown in Fig. 281, with the series winding in a section below the shunt, the depth of winding being in both cases as nearly as possible the same so as to give a neat appearance to the complete bobbin. Under these conditions it is evident that, in order to obtain an approximately uniform temperature rise over the length of the bobbin, the loss per unit length of winding space should be approximately uniform; *i.e.* if L_s and L_m are the axial lengths of the shunt and series coils respectively, and W_s and W_m are the watts lost in them, $\frac{W_s}{L_s} = \frac{W_m}{L_m}$, or $\frac{L_s}{L_m} = \frac{W_s}{W_m}$. In Chapter XVI, § 18, it was shown that the watts in any coil are $W = A^2T \times l_m \times k \times \frac{0{\cdot}00002445}{a}$, and since $a = \sigma \cdot a_1 = \sigma \cdot \frac{Lt}{T}$, we have in general $W = \frac{(AT)^2 \times l_m \times k \times 0{\cdot}00002445}{Lt\sigma}$, of in the present case, since the depth and the length of the mean turn are to be the same, $W_m \propto \frac{(AT)^2}{L\sigma}$. Hence $\frac{W_s}{W_m} = \frac{\frac{AT_s^2}{L_s \cdot \sigma_s}}{\frac{AT_m^2}{L_m \sigma_m}}$ and finally $\frac{L_s}{L_m} = \frac{AT_s}{AT_m}\sqrt{\frac{\sigma_m}{\sigma_s}}$. The total winding length of the coil being L, the correct length for the shunt coil is thus given by the relation $\frac{L_s}{L - L_s} = \frac{AT_s}{AT_m}\sqrt{\frac{\sigma_m}{\sigma_s}}$, or $L_s = L \times \frac{1}{1 + \frac{AT_m}{AT_s}\sqrt{\frac{\sigma_s}{\sigma_m}}}$

With copper strip for the series, and round wire for the shunt-winding, σ_m will be higher than σ_s, and $\sqrt{\frac{\sigma_m}{\sigma_s}}$ will be greater than unity, say, $\sqrt{\frac{0.85}{0.6}} = 1.19$. Since $\frac{AT_s}{AT_m} = \frac{6,090}{3,660} = 1.66$, the fractions of the total winding length which should be assigned to the shunt and series respectively are 0·665 and 0·335. If any great departure from this ratio be contemplated, the tendency should be in small machines to assign more space to the series-winding, so as to reduce its loss of watts, since this loss has the indirect effect of increasing the necessary armature E.M.F. and the ampere-turns to give the corresponding flux;[1] in large machines the opposite

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[1] The sections at the top and bottom of the coil will actually be cooler than the central section, but in the above this effect, due to the cooling influence of the end surfaces, has been neglected. On this latter approximate assumption, since in equation (129) the second term on the left-hand side, namely, $2Lt^2$ is not taken into account, it follows at once that, in order to satisfy the heating conditions, the axial length of any coil or part of a coil expressed in terms of the ampere-turns which it contains is

$$L\sqrt{t} = \frac{AT \times 10^{-3}}{1.225\sqrt{\sigma}}\sqrt{\frac{h}{\xi t}}\sqrt{\frac{t_s}{t_o}}$$

and since in our present case, with the shunt and series coils wound abreast, the only difference between them lies in σ, we have

$$\frac{L_s}{L_m} = \frac{AT_s}{AT_m}\sqrt{\frac{\sigma_m}{\sigma_s}}$$

Further, the current-density in the two kinds of winding is then inversely proportional to the square root of σ in the two cases.

If the series coils are wound over the shunt, or *vice versâ*, there is a further difference in that the mean length of a turn and the mean temperature of each division of the coil must depend upon its position. Let t_i, AT_i, h_i, σ_i refer to the inner coil, whether shunt or series, t_o, AT_o, h_o, σ_o to the outer coil, and let p_i, p_o be respectively the inside and outside perimeters of the complete coil; then the minimum watts with a given space to be filled are reached when the ratio of the depths is

$$\frac{t_i}{t_o} = \frac{AT_i}{AT_o}\sqrt{\frac{\sigma_o}{\sigma_i} \cdot \frac{h_i}{h_o} \cdot \frac{p_i}{p_o}}$$

With circular bobbins of which the inside diameter is d and the total radial course is better. When the total loss of about 1,280 watts is divided in the above proportion, the respective amounts are $W'_s = 850$ and $W_m = 430$; the latter corresponds to a loss over the series winding of 1·23 volts, which is thus higher than the allowance that has been made above. The difference is, however, but a very small percentage of the whole, and since a division of the winding into three equal sections conduces to the neat appearance of the coil as a whole, the total winding length of 6" will be divided between the shunt and series in the proportion of $\frac{2}{3} : \frac{1}{3}$.

The resistance which the shunt wire must have is from equation (124)

$$w' = \frac{220 \times 100}{5{,}800 \times 4 \times 1{\cdot}08 \times 1{\cdot}16} = 7{\cdot}55 \text{ ohms per 1,000 yards}$$

and the necessary gauge is therefore to be obtained by the use of wire 0·064" diameter with a small amount of 0·072" wire wound on one of the two sections. When the two sizes are insulated with 12 mils of double cotton covering to 0·076" and 0·084", in each section of 2" axial length there will be 25·2 and 22·8 turns per layer respectively, while the required depth of $2\frac{1}{4}$ inches will be given by 36 layers of the smaller size, and by a division of the second section into 25 layers of the smaller and 10 layers of the larger wire. The radial depth of the 25 layers will be 1·71" and the mean length of a turn $\pi(9{\cdot}875 + 1{\cdot}71)$ inches = 1·01 yard. Similarly, the depth

		Turns per layer.	Turns per section.	l_s in yards.	Yards.	
1st section	36 layers of 0·064	25·2	906	1·08	980	…
2nd ,,	25 ,, ,, 0·064	25·2	627	1·01	635	…
	10 ,, ,, 0·072	22·8	228	1·225	—	280
Per bobbin			1761	–	1615	280
In 4 bobbins			7044		6460	1120
w' per 1,000 yards				–	7·6	6·01
Resistance					49·1	6·74
					55·84 ohms	

depth is t, the ratio $\frac{p_t}{p_o} = \frac{d}{d + 2t}$ and with rectangular bobbins of which the two inside dimensions are A and B, $= \frac{A + B}{A + B + \pi t}$. Since the ratios $\frac{k_t}{k_o}$ and $\frac{p_t}{p_o}$ vary to some extent in opposite directions, the ratio of the depths reduces approximately to $\frac{t_s}{t_m} = \frac{AT_s}{AT_m}\sqrt{\frac{\sigma_m}{\sigma_s}}$ as before. In actual practice a large percentage difference in the value assigned to the ratio of the depths produces but a small percentage difference in the total watts, so that even an approximate division will not cause the watts to exceed the minimum appreciably.

of the outer layers of the larger wire being 0·79″, the mean length of a turn is $\pi(9·875 + 3·42 + 0·76)$ inches = 1·225 yard. When hot, $R_s = 55·84 \times 1·16 = 65$ ohms; thence $I_{s1} = \frac{220}{65} = 3·38$ amperes, giving $AT_{s1} = 5{,}950$ and 745 watts, while $I_{s2} = \frac{231}{65} = 3·55$ amperes, giving $AT_{s2} = 6{,}250$ and 820 watts under the full-load condition. There is therefore a small margin in hand. The total weight of the smaller wire is 240 lb., and of the larger 53 lb., making 293 lb. in all.

The series coils are to consist of wide copper strip wound on flatwise, and insulated with intervening strips of thin calico. The width may be nearly equal to that of the finished section, say, 1·9″, since the whole is to be bound over with cotton tape and the insulation beween the layers need not extend round the edges. Since the several sections of series-winding are to be connected in series from pole to pole, in order that the start and finish of each coil may be on opposite sides of the pole, there will be 10½ turns per section, and the depth of the winding will correspond to 11 turns. The thickness of each turn when insulated must therefore be $\frac{2·5}{11} = 0·227″$; and allowing 27 mils for the insulation between neighbouring turns, the copper strip is, for ease in winding, best divided into two thicknesses of 0·100″ wound together in parallel. Its area is therefore $1·9 \times 0·100 \times 2 = 0·38$ square inch, and its resistance per 1,000 yards at 68° F. $\omega' = \frac{0·02445}{0·38} = 0·0645$. The total length that is required is 42 turns × 1·08 = 45·4 yards, and its resistance $0·0454 \times 0·0645 = 0·00293$, or when hot, $R_m = 0·00293 \times 1·16 = 0·0034$ ohm. When carrying 350 amperes, the loss of volts over the series winding is thus 1·19, and of watts is 417, while the weight of the series winding is 200 lb. The total loss in the field-winding at full load is 1,237 watts or 1·55 per cent. of the output; it is rather less than in the corresponding shunt-wound machine—a result which is due to the better utilization of the space with the rectangular strip of the series winding, while the σ of the shunt winding has been kept up to the same figure, even though the size of wire is smaller, by the employment of a thinner insulation. The total weight of wire is correspondingly greater, namely, 493 lb.

In order to compensate for differences of temperature of the compound-wound dynamo it is convenient to insert in series with the shunt a rheostat, just as in the case of the simple shunt machine, but of much smaller range. The difference between the resistance of the shunt itself when hot and when cold would be compensated by the addition of an external resistance of 10 ohms; but since, when the whole machine is cold, the armature voltage which is required at full-load to give 230 volts at the terminals will be reduced to about 238, and only 9,500 ampere-turns per pole are needed, while the series winding still gives 3,660, the shunt current must be reduced to $\frac{5,840}{1,761} = 3{\cdot}3$ amperes; whence $R_s + R_r = \frac{231}{3{\cdot}3}$ $= 70$ ohms. The maximum resistance of the rheostat must then be at least $70 - 55 = 15$ ohms.

§ 20. Necessary imperfections of compound winding.—Although a dynamo may compound perfectly at full and no-load, it will not

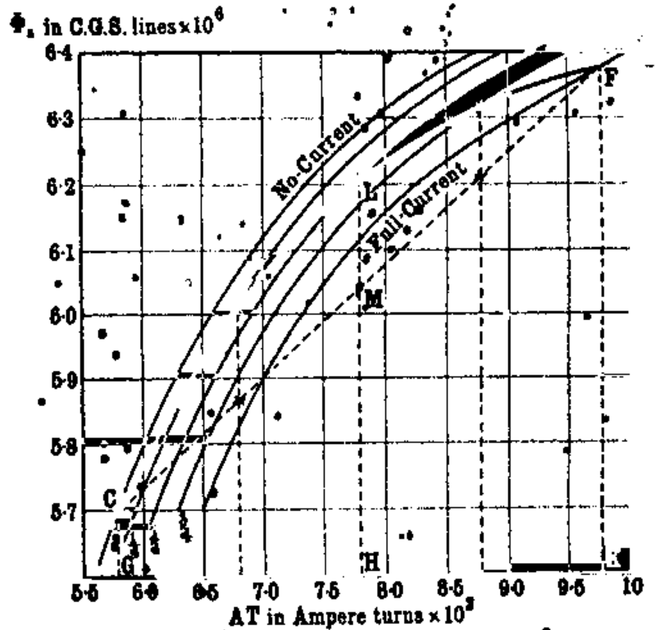

FIG. 300.

do so with equal accuracy at intermediate points. This is due partly to the flux curves being rounded between the working points of no and full load, as, *e.g.* between the limits of $5{\cdot}7 \times 10^6$ and $6{\cdot}38 \times 10^6$ lines in Fig. 274, and partly to the fact that when the brushes have to be given forward lead in the absence of commutating poles, the back ampere-turns at half-current are somewhat less than half the back ampere-turns at full-current, and those at quarter-current less than half of those at half-current, and so on.[1] The effect of these two causes is seen in Fig. 300, which shows a portion of the flux-curves of Fig. 274 on an enlarged scale. At no-load (or practically no-load) the working point of our compound-wound dynamo is C, and at full load F; since the length GK gives the increase in the ampere-turns, when the current is increased up to full load, the increase in the ampere-turns at half-load will be $GH = \frac{GK}{2}$, and the corresponding Φ_a on the half-current curve is HL. But for perfect compounding only HM lines are then required, and the result is that the voltage is rather higher than it should be; this, of course, increases the shunt-current, and the excess voltage is thereby rendered even greater. If therefore the terminal voltage is correct at no-load and at full load, it is higher than is required, not only at half-load, but at all loads between zero and the maximum. The excess voltage is roughly proportional at any point to the vertical distance between the full line CLF, and the dotted line CMF, from which it will be seen that it is greatest between quarter and half-load. In order to minimize this imperfection a compound machine should be worked as far as possible on the upper part of the flux-curves; the higher the working limits, the flatter and more horizontal do the curves become; and the effects of the unequal spacing of the intermediate curves, and of the increase of the shunt-excitation, are lessened. But in slow-speed machines, *e.g.* in an 18-kilowatt dynamo running at 250 revolutions per minute, the percentage loss of volts over its electrical resistance may amount to about 8 per cent. of the terminal voltage (6 per cent. over the armature and brushes, and 2 per cent. in the series coils); allowing a further loss of 3 per cent. in the leads between the dynamo and the lamps, and also a decrease of 5 per cent. in the speed of the engine at full-load, it will be found that Φ_a at full-load is $1{\cdot}11 \times 1{\cdot}05 = 1{\cdot}17$ times the no-load Φ_a, although the amount of over-compounding is not great. In such a case it is practically necessary to work the machine on the rounded knee of the magnetization-curve, since to work higher up would require an excessive amount of series wire. It results that slow-speed machines and those which have to work over a large range of voltage compound more or less imperfectly, and the terminal volts for any current between ¼ and ¾ of full load may be from 3 to 4 per cent. too high. In machines running at comparatively high speeds the voltage should not exceed the required amount by more than 3 per cent., even at the point of greatest difference.[1]

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[1] **Even if the brushes are retained in a fixed position the effect of the armature reaction in increasing the leakage helps to prevent the rise of the flux in the compound-wound machine from following the rise of the current in strict proportion.**

Machines with small magnets compound less perfectly than those with large magnets, and multipolars with their greater number of smaller magnetic circuits show in general a greater percentage rise at intermediate loads than would large 2-pole dynamos. Differences of temperature also considerably affect the perfection of the compounding of a dynamo; if worked on the rounded portion of the curve at no-load, and if the temperature of the field-coils rises during working 50° or 60° F., a machine designed to compound when hot will give too high a voltage at no-load, and, in general, as the temperature of the dynamo changes, the relative value of the shunt- and series-turns is altered. Such effects can, as mentioned above, be compensated by inserting a small variable resistance in the shunt circuit, which can be gradually short-circuited as the dynamo warms up during working. In other cases, where it may be necessary to alter the amount of compounding to meet different conditions, a diverter can be employed just as with a series-wound dynamo, or the series-turns are connected at intervals to contact-blocks, which enable some or all of them to be short-circuited by the insertion of a plug. Since the compound-wound machine is usually required to excite itself on open circuit, the same precautions must be taken against instability of the magnetism as in shunt machines.

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[1] Cp. Miles Walker, *The Diagnosing of Troubles in Electrical Machines*, p. 373.

Traction generators are very frequently wound to give 500 volts at no-load, and are then over-compounded to give 550 volts at full-load, so as to balance the loss of volts in the transmission line. Compound winding is also largely employed in the dynamos of isolated installations, as for driving motors in a factory or for the lighting of steamships, in order to maintain an approximately constant voltage on the motors or lamps under all conditions of load.

CHAPTER XVIII

THE FLUX-DENSITY CURVE ON NO-LOAD

I. THE SALIENT-POLE MACHINE

§ 1. The determination of the flux-density curve over a pole-pitch.—Given a salient-pole machine under design with a total number of ampere-turns AT_f of excitation on each pole, it is not possible to pre-determine the spacial distribution of the flux, *i.e.* the flux-density over a complete pole-pitch, without in the first instance assuming one or other of two closely related sets of quantities; and the accuracy of the assumption must subsequently be checked when it can be compared with the final result obtained by its means. If found to be inaccurate, it must then be corrected and the process repeated, until agreement is finally reached. The necessity for the initial judicious guess-work even for the no-load condition follows for the reason now to be given, and the same necessity also holds when the armature carries current.

In Fig. 301 the M.M.F. of a field coil, AT_f in ampere-turns, is marked in a circle on each pole. If 2 AT_c be the ampere-turns required to pass the flux from one bifurcation plane CD in the armature core below the teeth to the next bifurcation plane EF, the magnetic potential of the core in ampere-turns will be $+ AT_c$ at the bifurcation point under a N. pole, and $- AT_c$ at the bifurcation point under a S. pole. Either value will decrease numerically as we proceed from the bifurcation plane towards the interpolar plane of zero potential, and at each point x the potential will have some lesser value $\pm AT_{cx}$. The positive and negative values of the magnetic potential at the surface of the armature will under each pole be numerically higher by the ampere-turns expended over the reluctance of the teeth AT_{tx}. The magnetic potential of the N. and S. pole-faces will then be respectively $+ AT_p$ and $- AT_p$, where

$$AT_p = AT_{cx} + AT_{tx} + AT_{gx}$$
$$\text{or } AT_p - AT_{gx} = AT_{tx} + AT_{cx}.$$

If 2 AT_y be the ampere-turns required to carry the flux from one pole through the yoke to the next pole, the potentials at the roots of the N. and S. poles are respectively $- AT_y$ and $+ AT_y$; as the flux passes down through the N. pole, its potential is raised by the M.M.F. of the exciting coil AT_f less the loss AT_{pl} over the pole from $- AT_y$ to $+ AT_p$, while as it passes up through the S. pole, the potential is correspondingly raised from $- AT_p$ to $+ AT_y$.

Hence a second expression for the potential of the pole-face as obtained from the yoke side is

$$AT_p = AT_f - AT_y - AT_m.$$

All the above symbols have reference to one half of a magnetic circuit, corresponding to one pole, while the complete circuit calls for $X_f = 2\,AT_f$ ampere-turns of excitation.

Now AT_y, AT_m and AT_{cx} are at first unknown, since the total flux has not been exactly determined. Either then the total flux must be assumed from which to calculate AT_y and AT_m and thence to determine AT_p, or AT_p must itself be assumed as an initial datum. There is then only left the necessity either to guess the value of AT_c and thence by gradual reduction of it step by step as flux is removed from the core to obtain AT_{cx}, or to assume initially a certain distribution of the flux and by calculation from the gradually increasing core density to estimate provisionally the value of AT_{cx} at each point (cp. Figs. 327 and 329). In both cases the correctness of the assumptions can only be checked at the end of the process, but it is surprising how quickly such "trial and error" solutions converge on the true result.

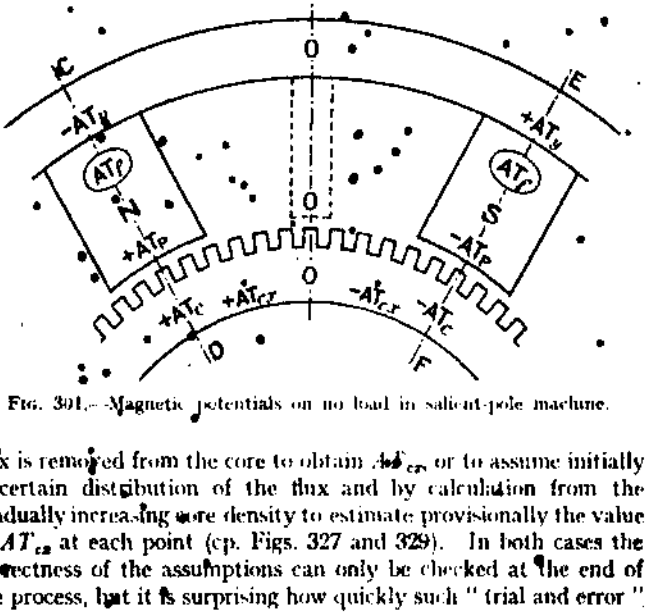

FIG. 301.—Magnetic potentials on no load in salient-pole machine.

§ 2. The core-density curve on no load.—On no load from considerations of symmetry the plane of zero magnetic potential passes radially down through the centre of the interpolar gap between two main poles, or down the centre of a commutating pole if such be present (as shown dotted in Fig. 301). Out of the yoke total ampere-turns $2AT_y$, the expenditure will be similar for equal distances on either side of the zero plane, and so also in the armature core for symmetrical points the numerical value of $\pm AT_{cx}$ will be the same. Starting from the bifurcation plane which must on no-load fall in line with the centre of the pole-face, *at* or the specific AT per cm. length of path increase at first but slowly, but as the flux-density in the armature core grows, it begins to rise very rapidly towards the pole-edge and then remains nearly constant over the part of the interpolar gap where the fringe is weak (Fig. 302). Conversely the integral of the curve or AT_{cx} as we proceed in the opposite direction from the interpolar line of symmetry to the pole-face centre rises at first rapidly and then becomes nearly flat under the pole.

As an example, in an 8-pole machine with toothed armature of diameter 45 ins. = 114·2 cm. with a pole-pitch of 45 cm. the polar arc was 33 cm., leaving an interpolar gap of 12 cm. so that $c = 6$. The equivalent air-gap length $Kl_g = 1{\cdot}11 \times 0{\cdot}795 = 0{\cdot}882$ and

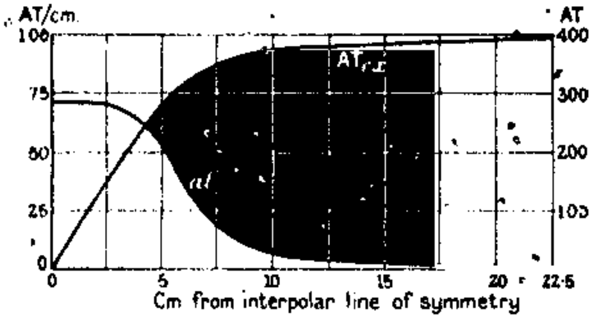

FIG. 302. AT_c over half magnetic circuit in armature core.

with a normal $B_g = 8400$, $AT_g = 5900$, while from Fig. 303 for this density in the air-gap $AT_t = \dfrac{0{\cdot}087 \times 8400}{1{\cdot}257} = 582$. The total flux over the polar arc would then be 8400 × 33 = 277,000 per cm. of armature core-length, and with allowance for the interpolar fringe, this was increased to 294,000 as the actual total flux of a pole-pitch per cm. of core. With deduction for insulation and air-ducts, and a depth of core 4·5 ins. = 11·4 cm. below the teeth, the single core-area per cm. axial length of core will be taken as $11{\cdot}4 \times 0{\cdot}9 \times 0{\cdot}83 = 8{\cdot}5$ cm², giving a maximum density in the core of 17,300, for which the *at* per cm. = 72. Thence AT_c under a pole was estimated at 390. The magnetic potential of a pole-face was thus $\mathfrak{A}T_p = AT_g + AT_t + AT_c = 5900 + 580 + 390 = 6870$.

If now the density in the air-gap at intervals of 2½ cm. over half the pole-pitch, obtained from equations (134) and (135) of the following section, be entered as shown in column 2 of Table X, the flux collected in each interval is given in the intermediate rows; the actual flux in the core at the points x, and the density B_c are then as shown in the 4th and 5th column respectively, opposite to the values of x. The average at over a section is given in the intermediate rows. The teeth of the armature being 4 cm. long, the mean diameter of the core below the teeth is $114{\cdot}2 - (8 + 11{\cdot}4) = 94{\cdot}8$. A cm. on the surface of the armature therefore corresponds to $1 \times \frac{94{\cdot}8}{114{\cdot}2} = 0{\cdot}83$ cm. length in the centre of the core, and $2\frac{1}{2}$ cm. on the surface correspond to 2·07 in the core. Multiplying the average at's by 2·07, and summing up the products, the value of AT_{cx} at each point x is reached in the last column.

TABLE X.

AT_c OVER ARMATURE CORE.

x cm. from interpolar centre.	B_{gx}	Flux per cm. length of core. Added in section.	Flux per cm. length of core. Total in arm. core.	Density B_{cx}	Specific at.	Average at for section.	× 2.07.	AT_{cx}
22·5	8370		0	0	0			395
		20,900				0·4	0·9	
20	8374		20,900	2,465	1			394·1
		20,910				1·1	2·3	
17·5	8382		41,810	4,930	1·2			391·8
		20,940				1·5	3·1	
15	8,390		62,750	7,390	1·8			388·7
		20,970				2	4·1	
12·5	8,400		83,720	9,850	3·1			384·6
		21,000				4	8·3	
10	8,410		104,720	12,360	6·4			376·3
		21,080				11	22·8	
7·5	8,420		125,800	14,800	18			353·5
		16,100				33	68·5	
5	8,560		141,900	16,700	54			285
		4,450				66	137	
2·5	1,000		146,350	17,250	71			148
		650				71·5	148	
0	0		147,000	17,350	72			0

§ 3. The air-gap flux-density curve on no load.—From the bifurcation plane the flux-density in the air up to a distance of l_s from the pole-edge is

$$1{\cdot}257\frac{AT_p - AT_{te} - AT_{ce}}{Kl_g} = 1{\cdot}257\frac{AT_p - AT_{ce}}{Kl_g + \mathcal{R}_{te}} \quad (134)$$

where $\mathcal{R}_{te}$ is the reluctance of the teeth corresponding to a sq. cm. of cross-section of the path in the air-gap, *i.e.* for a peripheral width of 1 cm. on the armature surface and an axial length of 1 cm. along the armature. No attempt is here made to determine the actual undulations of the flux curve due to the varying density over teeth and slots at the armature surface or at any other level in the air-gap. But the smoothed-out curve of density is obtained, from the area of which the total flux is correctly obtained. So important is the varying reluctance of the iron teeth that in the toothed armature it is best to consider the effect of $+TA_r$ and $-AT_r$ in relation, not to the armature surface, but to the cylindrical surface of the core at the level of the bottom of the slots. This may conveniently be done by calculating the equivalent reluctance of tooth per sq. cm. of path in the air, which is in series with the single gap. Thus if B_{gx} is the average density over a tooth-pitch

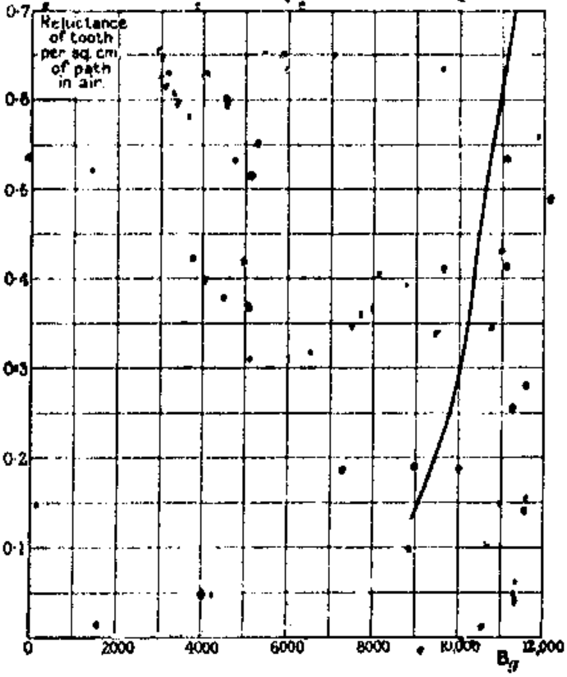

Fig. 303.—Tooth reluctance per sq. cm. of path in air-gap.

in the air-gap, the centre of the tooth-pitch being at point x, the equivalent tooth reluctance in series with the air-gap is—

$$\mathcal{R}_{tx} = \frac{\text{mean } H \text{ over tooth} \times l_t}{B_{gx}} = \frac{1{\cdot}257\, AT_{tx}}{B_{gx}}$$

From the data of the machine dimensions a curve such as Fig. 303 (which refers to the machine of § 2) can be plotted for the tooth reluctance per sq. cm. of air-gap for varying gap densities, and by reference to this values of B_{gx} and $\mathcal{R}_{tx}$ which are in agreement can quickly be found for any value of $1{\cdot}257\ (AT_x - AT_{tx})$:

Within the interpolar region, it has been stated in Chapter XVI., § 6 (a) that the counter effect of the adjacent pole dies away from its value on the interpolar line of symmetry very nearly to zero at the opposite pole-tip, and the rate of this decay may approximately be assumed as uniform over the half interpolar zone. The resultant flux-density on the armature surface in the interpolar gap for any distance x from the pole-corner up to $x = c$ would then, if the armature surface were throughout at zero potential, be closely represented by

$$1{\cdot}257\,AT_p\left\{\frac{m}{\xi x + Kl_e} - \frac{m'}{\xi c + Kl_e}\cdot\frac{x}{c}\right\}$$

where $\xi = 0{\cdot}9\gamma$ and takes into account the inclination of the pole-edges to the armature surface, and m' is the correction factor for c/l_e.

But the above approximation, as also the accurate solution of the ideal case upon which it is based, departs from the actual facts in assuming that the armature core is throughout at zero potential. In reality on the one side of the interpolar line of symmetry the armature core is at a varying positive magnetic potential AT_{cx}, being the ampere-turns expended over the armature core from any point x up to the interpolar line of symmetry, and on the opposite side it is at a varying negative potential $-AT_{cx}$. The effective AT over the air-path for flux from one pole is thereby decreased to $(AT_p - AT_{cx})$, and we are justified in assuming that the counter effect from the opposite pole is proportionately increased, the effective difference of potential becoming $-AT_p - (+AT_{cx}) = -(AT_p + AT_{cx})$. Next, the resultant AT_{tx} required by the tooth reluctance is that corresponding to the difference between the forward component flux from one pole and the counter component from the adjacent pole. The necessity for employing two different values AT'_{tx} and AT''_{tx} in the numerator for each component separately is at once avoided by inserting in the denominator of each item a term for the true tooth-reluctance. The final expression for the interpolar fringe from $x = 0$ to $x = c$ thus becomes—

$$1{\cdot}257\left\{\frac{m\,(AT_p - AT_{cx})}{\xi x + Kl_e + \mathcal{R}_{tx}} - \frac{m'\,(AT_p + AT_{cx})}{\xi c + Kl_e + \mathcal{R}_{tx}}\cdot\frac{x}{c}\right\}. \quad (135)$$

An approximate allowance for $\mathcal{R}_{tx}$ can alone be made in the first instance, but as soon as the pole-corner is left behind the density falls so quickly that the tooth reluctance becomes practically almost a negligible quantity. On the interpolar line of symmetry $m = m'$, $\mathcal{R}_{tx}$ vanishes, and also AT_{cx}, so that the resultant density is zero. No lines enter or leave through the armature surface, but the direction of the real flux just grazes the tooth-tip tangentially (cp. Fig. 249).

In this manner a close approximation to the flux-density curve over a pole-pitch on no-load can be made when the varying undulations due to the movement of slots and teeth are not immediately required.

II. THE NON-SALIENT-POLE MACHINE

§ 4. The distributed field-winding of the non-salient-pole machine.—In the cylindrical rotor of a non-salient-pole machine the exciting coils are embedded in slots which are distributed over a certain portion of its periphery. The number of slots and the fraction σ of the pole-pitch over which they are spread vary in different makes, but the practical range of variation is not great. Concentration of the winding in a single slot or in a very few per pole would be favourable to the production of a large magnetic flux for a given value of the ampere-turns of excitation. But the possible width and depth of a single slot are limited; if open and wide, it will cause exaggerated tooth ripples, and the accumulated mass of copper will be difficult to secure mechanically and to cool effectively. With an increase in the number of slots the intervening teeth greatly assist in conducting the heat to the surface where it may be carried away by air driven through the air-gap, and further, when the slots are partially distributed, a greater number of ampere-turns can be accommodated per pole. On the other hand, if the winding is distributed over the whole of the pole-pitch, the inner turns are comparatively ineffective, so that nothing is gained by making it extend over more than 80 per cent. of the pole-pitch.[1] A compromise must therefore be struck, and usually the wound fraction of the pole-pitch falls in practice between the limits of $\sigma = 0{\cdot}6$ to $\sigma = 0{\cdot}8$ with from 6 to 10 or 12 wound slots per pole.

In these circumstances the unwound pole-centre may be uniformly slotted in order to maintain the same magnetic relation to the air-gap as holds over the wound portion, but more usually it is left unslotted (Figs. 234 and 235) as giving the greatest permeance, or it has smaller grooves closed by magnetic wedges to give a smooth surface, such grooves being used for purposes of axial ventilation. On the average then it may be said that two-thirds only of the pole-pitch are wound, one-third of the pole-pitch forming a pole-centre which in a minor degree acts like a salient pole, and, so to speak, holds the flux more or less bound to itself.

§ 5. The trapezium of M.M.F.—When the exciting winding is located in two or more slots per pole, the sides of the spacial curve of the M.M.F. plotted in relation to one pole-pitch developed on the flat are stepped, and when the fraction σ of the pole-pitch Y only is wound, the curve has a flat top extending over $1 - \sigma$ of the pole-pitch. In the extreme cases of a winding perfectly uniformly distributed over the pole-pitch or $\sigma = 1$, the M.M.F. curve per pole is a triangle, of height $IT_m/2$ in ampere-turns, where I = the exciting current and T_m is the number of conductors per pole, and if the winding is closely concentrated in one slot per pole, it is a rectangle of the same height. Between these two limits lie all the intermediate cases of practice. Since the M.M.F. rises steeply at the same rate within each slot (when uniformly filled) as we pass from one wall to the other, a continuously sloping line may without much error be substituted for the stepped sides, as shown dotted in Fig. 304, and a regular trapezium of M.M.F. as acting on the half magnetic circuit corresponding to a pole is obtained.

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[1] Cp. Dr. S. P. Smith, "The Non-salient Pole Turbo-alternator," *Journ. I.E.E.*, Vol. 47, p. 563.

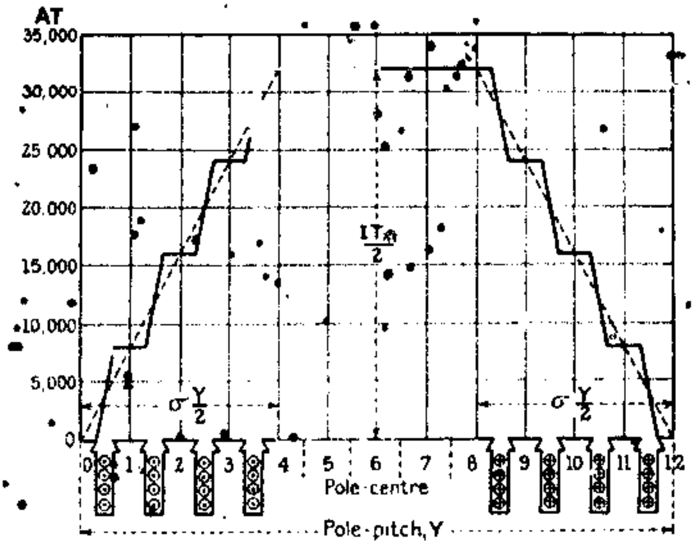

Fig. 304.—The M.M.F. trapezium.

§ 6. Allocation of the M.M.F. to component parts of the magnetic circuit.—This M.M.F. has then to be allotted in proper proportions to the several parts of the magnetic circuit—stator core, stator teeth, air-gap, rotor teeth and rotor core. As in the case of the salient-pole machine (§ 1), in order to determine the shape of the flux-curve either the *AT* expended over rotor and stator cores, or the maximum flux through the rotor core, must provisionally be guessed at the outset.

Of the two, it is best to assume the former, thence to determine approximately the total flux, and lastly to check the first assumption, before proceeding with more detailed calculations. From

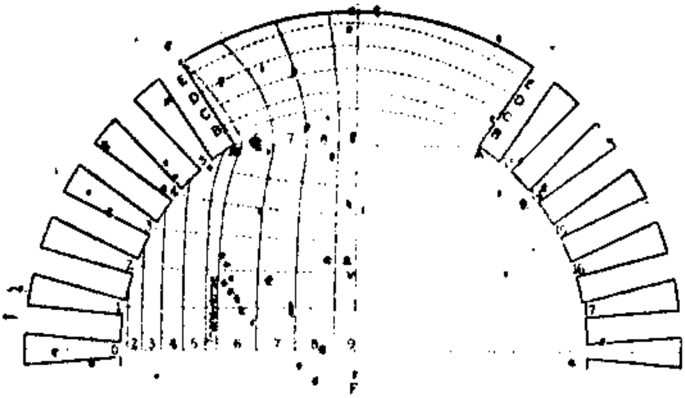

FIG. 305.—Division of rotor core by equipotential surfaces on no load.

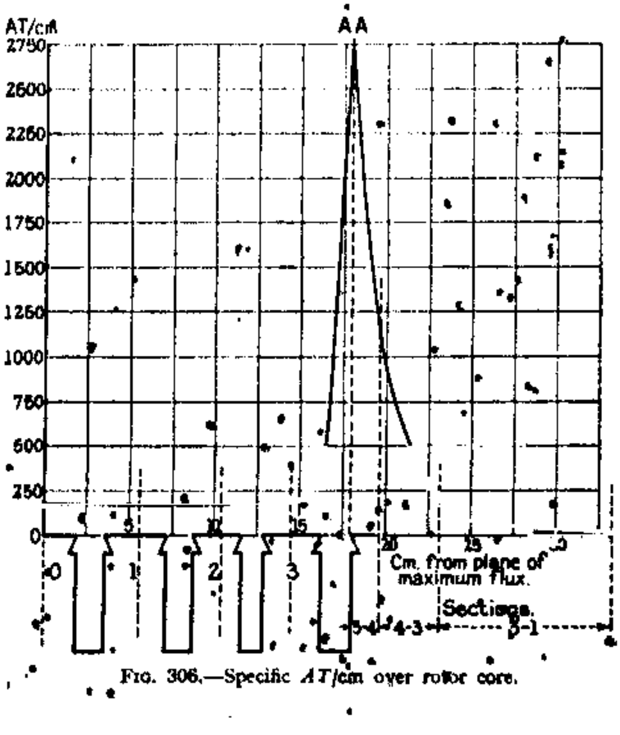

FIG. 306.—Specific AT/cm over rotor core.

considerations of symmetry, on no-load only one half of a pole-pitch need be considered.

Starting from a point opposite to the pole-centre, the curves for the specific *AT*/cm for the stator core, and for its integral in the

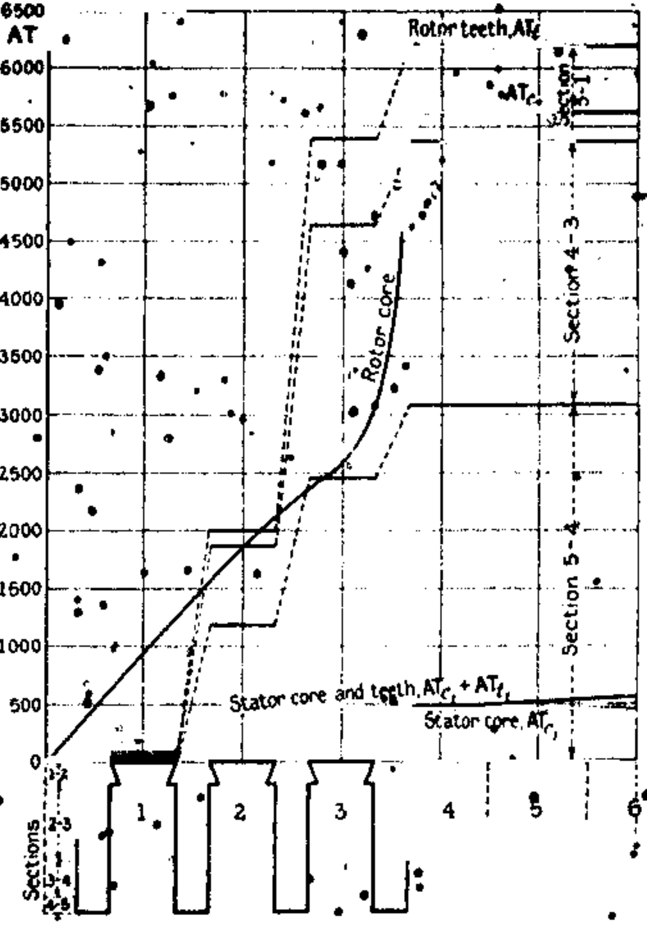

Fig. 307.—*AT* expended over component parts of the magnetic circuit.

reverse direction resemble those of Fig. 302. The experiments of Mr. Carl J. Fechheimer already mentioned in Chapter XIV, § 12, show that in a deep stator core the flux distribution is almost sinusoidal; if therefore the stator pole-pitch is divided up into small sections, each, say, 5 electrical degrees, and the maximum density averaged over the half core-section is taken as the starting-point, the value of the density at each step of 5° therefrom is found in proportion to the cosine of the angle in electrical degrees; thence the specific AT/cm is obtained from a B-H curve for the sheet-steel, and when summed up, AT_{c2} for any distance from the plane of maximum flux or zero potential. The ampere-turns AT_{t1} for the stator teeth opposite the centre of each rotor tooth are obtained from a curve similar to Fig. 303, but are comparatively unimportant, as appears from Fig. 307.

The rotor core is treated by division into sections corresponding to rotor tooth-pitches, and bounded by equipotential surfaces after

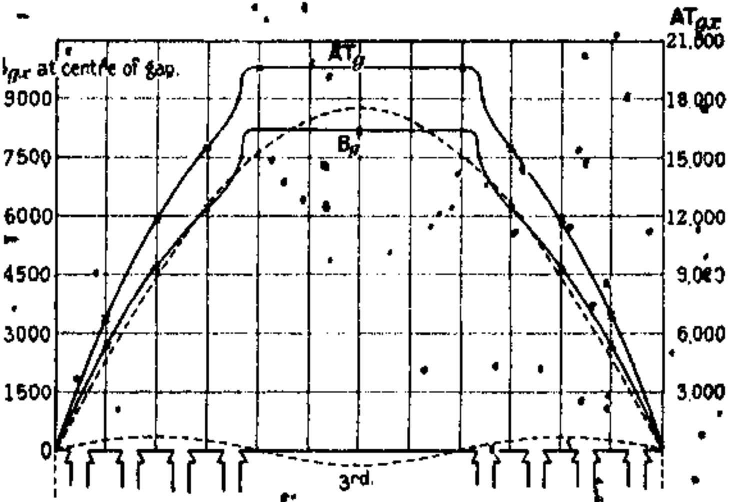

FIG. 308.—AT_g and B_g of non-salient-pole rotor on no load.

the manner of Fig. 305. The specific AT/cm or at for each section will depend on the density of the flux in the rotor core as affected by the presence or otherwise of axial ventilating holes or ducts through the core; but usually it is found to remain fairly constant from the plane of maximum flux up to the last tooth-pitch before the equipotential plane AA across the neck of the pole-centre. When this is closely approached, the density and the specific AT/cm rise very rapidly, as shown in Fig. 306. The integral again yields a continuous curve marked as AT_{c2} in Fig. 307 and rising very steeply towards AA, over which it remains constant; for the further passage of the flux, the unslotted pole-centre is reckoned as a single large rotor tooth or is divided up mentally into rotor tooth-pitches, as 4, 5, 6 in Fig. 307.

The AT expended over each rotor tooth increase greatly as the pole-centre is approached, and are marked as AT_{n} in Fig. 307, which also includes the pole-centre regarded as a tooth.

Adding up, then, the component items, $AT_{c1} + AT_{t1} + AT_{n} +$ AT_{n} of Fig. 307 for the centre of each rotor tooth,[1] and deducting their sum from the corresponding values of the exciting ampere-turns of Fig. 304, the differences give AT_g acting on the air-gap opposite each rotor tooth (Fig. 308). The effective length of this gap has two values according as it exists between the surfaces of rotor and stator where both are slotted or between the slotted stator surface and the unslotted surface of the pole-centre, to which may be added a third intermediate value for the tooth-pitch at the edge of the pole-centre which is only slotted on the one side. The values of B_{g1} thence deduced for each rotor tooth are marked by the crosses on the lower full-line curve of Fig. 308, the whole of the values employed in Figs. 304, 306–8 being derived from the 2-pole 3000 kW. 3-phase turbo-alternator analysed by Mr. S. Neville in his paper (Part III) supplementing the present writer's Part I on the Flux-Wave of the Turbo-alternator in *Papers on the Design of Alternating Current Machinery*.[2]

§ 7. The rotor transverse slot flux.—The difference from the analogous case of the salient-pole machine lies mainly in the additional complexity introduced by the transverse component of the flux crossing the rotor slots. As explained in detail in the above-quoted paper, the difference of magnetic potential in ampere-turns acting at any height x between the walls of a rotor slot of depth h_w below the wedge may be expressed as

$$AT_r \frac{x}{h_w} - AT_c \frac{w_t}{t_r} - (AT_x' - AT_x) \quad . \quad . \quad . \quad (136)$$

where AT_r are the ampere-conductors of one rotor slot, and AT_c are the ampere-turns expended over the rotor core between the centres of two adjacent teeth for which AT_x' and AT_x are the ampere-turns expended over their reluctances up to the height x from the bottom of the slots. Here AT_x' relates to the tooth farther from, and AT_x to the tooth nearer to, the plane of maximum rotor flux. The difference of potential thus varies greatly with the varying values of AT_x' and AT_x. Near the plane of maximum flux AT_x' always exceeds AT_x owing to the increase of the flux-density as we proceed up the side of the flux-curve, but for the unslotted pole-centre AT_x' will not so greatly exceed AT_x or may even be less. In the latter case, the bracketed term is negative, and the whole term with its sign becomes positive, increasing the transverse component due to AT_r. In consequence the transverse flux may be greater within the slot at the edge of the pole-centre than at the centre of the exciting coil, and may decline to a minimum in an intermediate slot. Such a case is indicated in Fig. 309. The difference between the amount of the flux entering one side and leaving on the other side of a tooth within any section of its height is added to or subtracted from the radial component flux proceeding up or down the tooth, and is thus an addition to or a deduction from the useful flux passing through the air-gap into the stator surface.

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[1] The full line values of AT_{n} are only joined up by dotted lines for convenience in following, and Fig. 307 must only be read on the centre lines of the teeth.

[2] Pp. 240–252 (Pitman & Sons

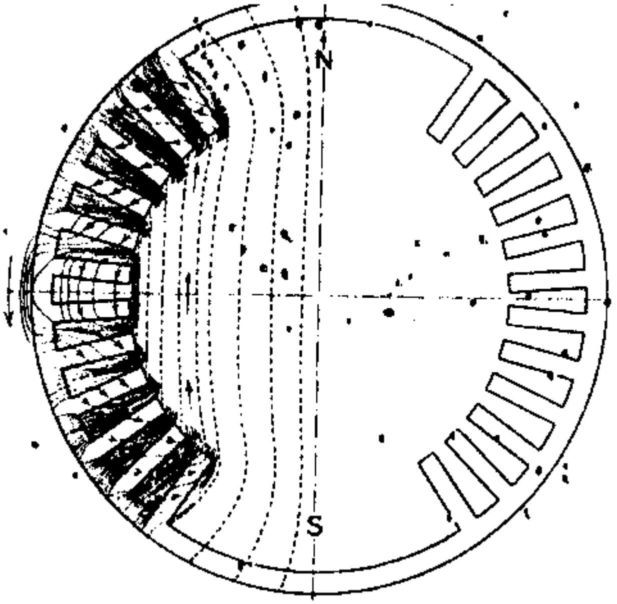

FIG. 309.—Rotor slot flux on no load.

The several items of the transverse M.M.F. can be isolated and considered separately, each as causing its own component in the transverse slot flux. But of these items the first two can be grouped together as being independent of the tooth reluctance and as being a nearly constant quantity until the tooth-pitch next to the edge of the pole-centre is reached. Here the rotor tooth-pitch λ_2 must be interpreted as the distance only from the equipotential plane *AA* to the next lower equipotential surface, and the high value of the *AT*/cm over the part next to *AA* forces a larger amount of the total rotor flux out of the core into the slot.

To deal with the varying item of the tooth reluctance and the varying difference of potential that thence arises, each tooth is best divided into at least three sections of height decreasing towards the root of the tooth where the saturation is greatest, as shown at the foot of Fig. 307. It is then simplest to calculate, first, the transverse flux that would be caused by AT_s' for any section if the opposite wall of the slot were at zero potential, and secondly the transverse flux that would be caused by AT_s for the similar section if the wall of the slot formed by the face of the tooth first considered be imagined in turn to be reduced to zero potential;[1] the algebraic difference of the two fluxes thus found will then be the actual component due to $AT_s' - AT_s$ for the considered section. Lastly, deducting this flux from the similar quantity for the next slot nearer to the plane of maximum flux, the difference is the flux added to or subtracted from that at the end of the section nearer to the rotor core, and, if positive, it is added thereto within the section. The process is fully illustrated by a worked example in Part III of the second *Paper on the Design of Alternating Current Machinery* and need not here be repeated.

§ 8. End-bell leakage.—The end-connections of the exciting coils are retained in place by end-bells, for which nickel steel is usually employed. Since this material is magnetic, and the edge of the bell abuts against the rotor body or is separated therefrom only by a small intervening air-gap, lines of flux escape from the tips of the rotor teeth and from the curved tip of the pole-centre into the end-bell. They are thus lost so far as any useful action is concerned, since they do not pass through the air-gap into the stator, but complete their path through the substance of the end-bell and re-enter the tips of the rotor teeth and pole-centre under a pole of opposite sign. The amount of this true *leakage* is very considerable, and thereby a further difference is introduced between the non-salient-pole and salient-pole cases.

The course of the leakage flux over a half pole-pitch is indicated with a few equipotential lines in Fig. 310, which shows the portion of the bell at one end developed on the flat. A first estimate of its total amount can be made by taking a somewhat smaller value than ½ AT_r as acting over the half tooth-pitch between the lines AB' and OO. From the AT/cm thus obtained the density for the steel employed is found, and this, when multiplied by the area of cross-section, gives a figure for the total leakage. Assuming certain values for the potentials of each rotor tooth at its tip, the process is continued, and the difference in the values as each tooth-pitch is passed is regarded as the leakage of the tooth-pitch. When the AT acting on each tooth-pitch has reached its minimum, trial must then be made as to how nearly the remaining flux can be carried round the curved paths by the remaining differences of potential, after the manner of Fig. 310. Adjustment of the equipotential lines by raising their outer ends through the distances D to D', F to F', will then enable a reasonable estimate to be made of the

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[1] As proposed by Mr. Neville in the above quoted paper.

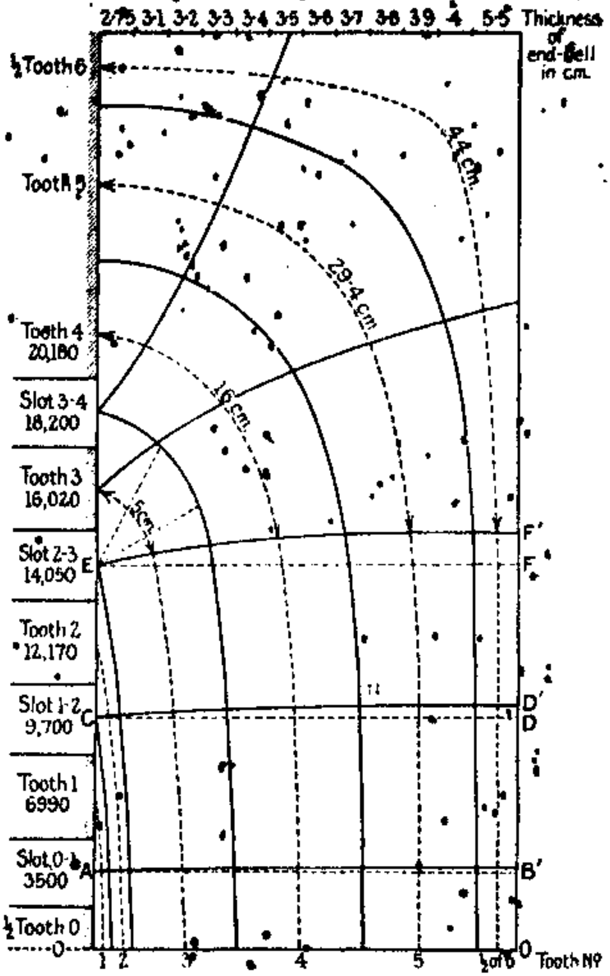

Fig. 310.—End-bell leakage.

maximum flux that the potentials of the tooth-tips and pole-centre can cause.[1] Generally the section of the end-bell on the plane of maximum rotor flux becomes saturated to a density of some 18,000 to 20,000 C.G.S. lines per sq. cm. The longer the rotor core, the less the percentage loss of flux by leakage into the end-bells.

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[1] See *Papers on the Design of Alternating Current Machinery*, pp. 199-201, for further details.

§ 9. The fundamental of the flux-density curve.—The importance of the fundamental B_{g1} in relation to the E.M.F. has been emphasized in Chapter IX, § 14, and it is evident that it is mainly dependent on the height of the flux-density curve over the flat portion corresponding to the pole-centre, and that when this has been determined, the value of the fundamental follows with but little range of variation for a given ratio σ.

If the AT expended over the rotor and stator cores and teeth increased in strict proportion to the distance or number of teeth

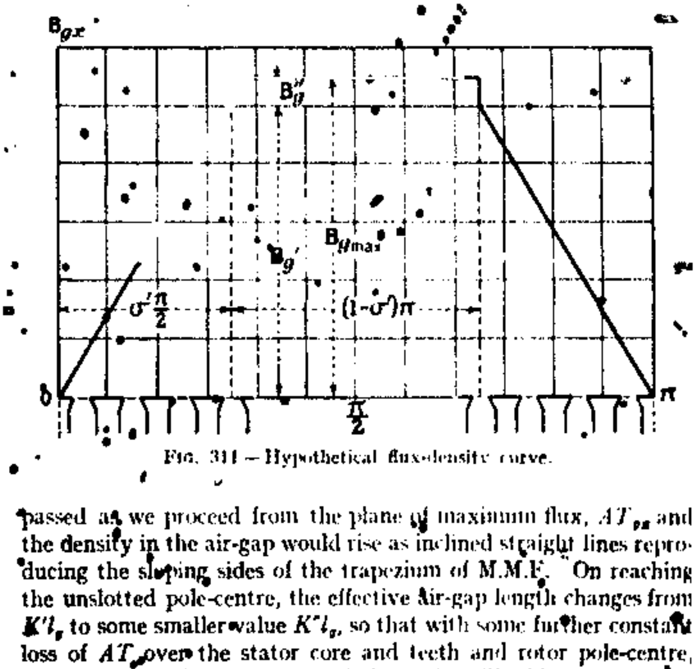

FIG. 311.—Hypothetical flux-density curve.

passed as we proceed from the plane of maximum flux, AT_{gs} and the density in the air-gap would rise as inclined straight lines reproducing the sloping sides of the trapezium of M.M.F. On reaching the unslotted pole-centre, the effective air-gap length changes from $K'l_g$ to some smaller value $K''l_g$, so that with some further constant loss of AT over the stator core and teeth and rotor pole-centre, deducted from $IT_m/2$, the remainder AT_{gs} will add a rectangle of flux over some fraction of the pole-pitch. The point of rapid rise of the density may be fixed at the centre of the slot nearest to the unslotted pole-centre. If γ_s = the pitch of the rotor slots in electrical radians, the flat portion of the flux-density curve extends over an angular width in radians of $(1-\sigma')\pi = (1-\sigma)\pi + \gamma_s$, and each sloping side over a width $\sigma'\frac{\pi}{2} = \sigma\frac{\pi}{2} - \frac{\gamma_s}{2}$. That is, $\sigma' = \sigma - \frac{\gamma_s}{\pi}$, or, if the slots are pitched as for a number s per pole,

$\sigma' = \sigma - \frac{1}{s}$. The flux-density curve then has the geometrical shape of Fig. 311, which may be split up into a trapezium of height B_g' and a rectangle of height B_g'', the two together making up the height $B_{g\,max}$.[1]

The general expression for a trapezium in which the height B_g' extends over a fraction σ' of the pole-pitch (Fig. 312) is

$$B_x = \frac{8}{\pi^2} \times \frac{B_g'}{\sigma'}\left(\sin \sigma'\frac{\pi}{2}\sin\theta_x + \frac{1}{9}\sin 3\sigma'\frac{\pi}{2}\sin 3\theta_x + \ldots\right) \quad . \quad (137)$$

and the general expression for a rectangle of height B_g'' extending over the same fraction of the pole-pitch when the origin is at a point

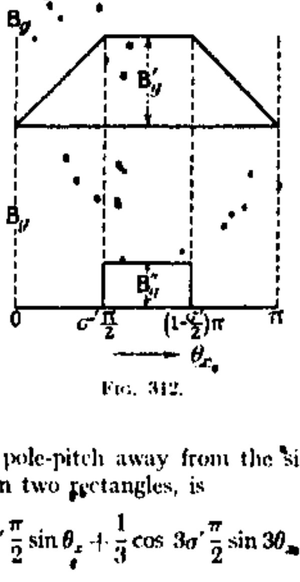

FIG. 312.

distant $\sigma'/2$ of the pole-pitch away from the side of a rectangle, *i.e.* midway between two rectangles, is

$$B_x = \frac{4}{\pi}B_g''\left(\cos \sigma'\frac{\pi}{2}\sin\theta_x + \frac{1}{3}\cos 3\sigma'\frac{\pi}{2}\sin 3\theta_x + \ldots\right) \quad . \quad (138)$$

The value of B_x for the combination is given by the sum of the two expressions, and the amplitude of the joint fundamental is

$$B_{g1} = \frac{4}{\pi}\left\{B_g'\frac{\sin \sigma'\pi/2}{\sigma'\pi/2} + B_g''\cos\sigma'\pi/2\right\} \quad . \quad . \quad (139)$$

If *e.g.* we assume $\sigma = \frac{2}{3}$rds, and the slots are pitched as for 12 per pole, as in Fig. 308, $\sigma' = \frac{8}{12} - \frac{1}{12} = \frac{7}{12}$, and

$$B_{g1} = \frac{4}{\pi}\left\{0{\cdot}866\ B_g' + 0{\cdot}6088\ B_g''\right\}$$

---

[1] See Dr. S. P. Smith and R. S. H. Boulding, "The Shape of the Pressure Wave in Electrical Machinery," *Journ. I.E.E.*, Vol. 53, pp. 211–14.

Although the corners of the rectangle and the junctures of the sloping sides with it are in reality rounded off, the double value of the flux-density on the line of the juncture indicates that at this point, the same value of AT_g divided by $K'l_g$ and by $K''l_g$ yields the two values B_g' and $B_{g\ max}$. If the ratio of the two values of the effective air-gap length be, as usual, about 0·955, $B_g' = 0·956\ B_{g\ max}$ and $B_g'' = 0·0448\ B_{g\ max}$. Thence

$$B_{g1} = \frac{4}{\pi}\left\{0·828 + 0·027\right\} B_{g\ max}$$
$$= 1·09\ B_{g\ max}$$

But the above case would only be reproduced at low values of $B_{g\ max}$. When the teeth become highly saturated, the sides of the curve become strongly bowed or concave to the horizontal axis, owing to the increasing *proportion* of the total AT expended over their reluctance, and the height of the rectangle becomes proportionately greater. Both effects are illustrated in Fig. 308, for which the amplitude of the fundamental (shown dotted)[1] is closely 8800 as compared with $B_{g\ max} = 8200$, *i.e.* $B_{g1} = 1·07\ B_{g\ max}$. Hence for purposes of design, B_{g1} may be taken as, say, 1·09 to 1·05 $B_{g\ max}$ over the working range. At no load under full load excitation—a condition which may require to be tested in order to calculate the inherent regulation of the alternator—B_{g1} may sink to equality with $B_{g\ max}$.

§ 10. The practical process of design.—The necessity at the outset for a provisional estimate of the total flux has been stated in § 6, and we are now in a position to show how it can be quickly made and immediately checked, and the value of $B_{g\ max}$ be thus determined for a given excitation or *vice versâ*.

Assuming $AT_{c1} + AT_{t1}$ ampere-turns as expended over the stator core and teeth, and $AT_{c2} + AT_{t2}$ for the corresponding items in the rotor core up to the equipotential plane AA and onwards up to the surface of the unslotted pole-centre, the difference $IT_m/2 - (AT_{c1} + AT_{t1} + AT_{c2} + AT_{t2}) = AT_g$ acting between pole-centre and stator face. Dividing by 0·8 $K''l_g$, the density $B_{g\ max}$ is found, which practically will hold over the pole-centre or $1 - \sigma'$ of the pole-pitch, save for a small falling off towards its edges.

Multiplying $B_{g\ max}$ by the effective air-gap area over half of the pole-centre, the flux in the single section of the stator core opposite to the pole-centre edge is obtained. The same value of AT_g divided by 0·8 $K'l_g$ gives a value for B_g' at the juncture of rectangle and trapezium which cannot be exceeded and when the rotor teeth are highly saturated will not be reached. Plotting therefore a slightly

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[1] The amplitude of the 3rd harmonic shown at the foot of the diagram is 366 = [illegible]3 per cent. of the fundamental.

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EDITOR'S INTRODUCTION

On page 243 the author of this book puts his finger upon one of the weaknesses in the present situation regarding industrial education, and at the same time points out one of the most fruitful fields of effort. He says, "One of the great problems connected with vocational education is the systematic training of a sufficient number of instructors for existing and proposed vocational schools." The lessons of our industrial unpreparedness as revealed by the war have not been lost; never in our history has there been such a keen realization of the dependence of production upon skill, and the part that wise methods of training can have in cultivating skill. A few years ago we were greatly concerned about supplying skilled workers; now we realize the equal necessity of training men and women to utilize the skill which the workers bring to their daily employment; hence the demand for training foremen and employment managers. In our ways and means for meeting these increasing demands we are at once fortunate and unfortunate; fortunate in adequate financial support for sound instructor training plans; unfortunate in a shortage of people to organize and direct them, and doubly unfortunate in a lack of organized practical material for use in instructor (teacher) training classes.

Teacher-training under the terms of the Smith-Hughes Act occupies a unique position in that a considerable amount of money may be made available at the very outset of the work — a condition which has rarely existed in American educational history when new types of education have been proposed. The law itself makes an allotment of money to every State for teacher-training in the fields of agriculture, home economics, and trade and industry; it provides that not less than twenty per cent nor more than sixty per cent of the whole shall be expended in any one of the three fields, and further provides that every dollar of Federal money so expended shall be matched by a dollar from State or local sources. The small States of the Union are allotted at least $5000 for training teachers. If the State Board of Education of a small State should decide to spend only the minimum amount possible — twenty per cent — this State would have $1000 of Federal money to be matched by $1000 of State or local money, and would have, in all, not less than $2000 to be expended for the training of teachers for service in trade and industrial schools. Should the Board of Education of a small State decide to spend sixty per cent, the maximum amount possible for this work, this State would have available $6000. From these sums the amounts vary until we have the possibility of an expenditure for this work of approximately $170,000 in the most populous State.

The problem of teacher-training is an imminent one for several reasons. (1) There will be a constantly growing demand for suitably qualified teachers as the States put into operation their plans for trade and industrial schools. (2) Each of the States accepting the benefits of the Federal Act for industrial education, must, by the terms of the act itself, not later than 1920 begin its program of training industrial and trade-school teachers. (3) A wise expenditure of public money makes it incumbent upon all concerned with the administration of industrial education, that methods and content of teacher-training courses be formulated at the earliest possible moment.

The content of a teacher-training course for teachers of trade and industrial subjects is determined by two considerations, what to teach and how to teach. The content of what to teach is determined by the kind of knowledge and information needed by the workmen skilled in the field in which the teacher works. The problem of training a skilled man, efficiently and expeditiously to teach others what he himself knows is the vital part of such a teacher-training course.

Wherein does a training course for vocational teachers differ from a course designed for any other group of teachers? This question has been frequently discussed for several years, but it is doubtful if at the present time there is general agreement throughout the country as to the content of a course for vocational teachers and a clear definition of differences. The phrase "professional training" for any group of teachers is not well defined. A variety of courses have been developed at many institutions and every year the study of education brings new developments. In college and university catalogues to-day we see long lists of courses having to do with education, frequently worked out in great detail and minuteness. Such courses as are suggested by the following topics are frequent:

History of Education.
Principles of Elementary Education.
Principles of Secondary Education.
Organization and Administration of Elementary Education.
Organization and Administration of Secondary Education.
Educational Psychology.
General Method of Teaching.
Special Method of Teaching Particular Subjects.
Observation of Schools.
Practice Teaching.

An examination of the catalogues of educational institutions throughout the country will show that every one of these topics has been applied to vocational education.

One charged with organizing a course primarily intended to train teachers in vocational schools faces a bewildering mass of material if he attempts to make his course comparable to those developed for elementary- and secondary-school teachers. It may not only be bewildering, it may be discouraging, and yet, somehow or other, those charged with the administration of vocational education have to solve, as well and as fully as possible under existing conditions, the problem of securing properly trained people to serve in trade and industrial schools.

There is a belief that professional study will help in preparing those teachers, but the term "professional study" is very elastic, and, doubtless, several years of experimentation must elapse before there is general agreement regarding the minimum amount of professional study acceptable either in terms of time devoted to such study or the content of the course.

Whatever the course should include, it must be closely correlated with the kind of schools to be developed in a given locality. It should also be kept constantly in mind that the aim of the vocational school is specific and the school presents problems peculiar to that type of school. These problems are not those of an elementary or a high school. They are conducted for different purposes; their results are tested by different standards; they deal with different groups of people, with different methods of teaching, different equipment: and further, the particular problems of the vocational school, taking the country at large, have not been made the subject of special consideration in established institutions; also, if the vocational school serves its purpose it must be kept in the most intimate contact with industrial resources and industrial conditions in its locality.

In other words, the vocational field of training is an ever-changing one. All these conditions make different demands upon teachers and upon those who would train teachers than are presented by the regular public schools.

The plans for teacher-training, on analysis, show a recognition of four qualifications or sets of qualifications desired in a teacher:

(1) He should be master of the subject he proposes to teach.
(2) He must be able to deal sympathetically and intelligently with adolescents and adults.
(3) He must know something of the relation of industrial education to other fields of human endeavor.
(4) He must know how to teach.

Every teacher-training course, or every subject proposed for study in such a course, may well be challenged on the ground of what it can contribute to producing or cultivating one or more of these four qualifications of a teacher. Anything that does not contribute to one of these four qualifications is superfluous, because the time available for relevant matter is all too limited. The amount of time available in any proposed scheme of teacher-training is very limited and must be utilized in the most effective way. Every proposed course should, therefore, be challenged on the ground of its selection of field in which the student is to spend his time; that is to say, if we wish to produce a teacher of carpentry for a unit trade school or an evening trade extension school, what work should he take in order to make his teaching most effective? Obviously, if he is assumed to be a master of his trade — and no others are at present being discussed — we shall not give him further practice in his trade as a carpenter. But judging by the proposals that have been made, beyond this one thing there is little agreement on what he shall be given in order to become an effective teacher in a school. We note courses bearing such labels as these:

Principles of Vocational Education.
Current Practices in Vocational Education.
The Psychology of Vocational Education.
Industrial and Trade History.

Numerous others might be cited.

Running all through proposed teacher-training courses there seems to be assent to the proposition that the tradesman who is to become a teacher needs to be trained in *how to teach*, but what he is to do, or what he shall study to bring about this result, is, as yet, an unsolved problem.

Such considerations as these have evidently been in Mr. Dooley's mind as he has brought together the material for this book, out of his years of experience as a director of trade and technical schools, as a trainer of teachers, as an organizer of courses, and as a student of the many and varied phases of vocational education. Only in a secondary manner does this book deal with the art of teaching; its value lies in its compact summing-up of facts and principles, its "sampling" of methods and devices in organizing material for purposes of instruction, all of which, when handled by a live teacher of teachers, will be a constant stimulus to the members of the class to draw upon their own stores of knowledge and experience, to focus their thinking upon the problems at hand, and to justify their solutions by clear reasoning on adequate data, rather than by dogmatism. The best book is one that compels thinking, the poor book offers ready-made solutions; this book happily avoids the latter.

The real teacher will always want to know the relation of his part of the work to the whole field. This book presents a valuable combination of "high lights" and "background."

The unit of thought in each chapter is reinforced by a series of thought-provoking questions and a skillful selection from the literature of the subject, which should be of great value not only in the actual work of the teacher-training class, but also as the constant companion of the teacher in his efforts to make himself a better teacher.

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PRINCIPLES AND METHODS OF INDUSTRIAL EDUCATION

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FOR USE IN
TEACHER TRAINING CLASSES

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